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PLEISTOCENE ARTIFACTS AND ASSOCIATED FOSSILS FROM BEE COUNTY, TEXAS

BY E. H. SELLARDS

With Notes on Artifacts, by T. N. Campbell, and
Notes on Terrace Deposits, by Glen L. Evans.

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ABSTRACT

This paper contains the results of a study of human remains—artifacts, workshops, camp sites, and hearths—and of the associated animals found in the Berclair terrace deposits of the Mission River drainage system of the Coastal Plain region of Texas. The artifacts are referable to Folsom, Yuma, and cultures known from central Texas, and some are not definitely placed as to cultural position. The Folsom and Yuma cultures are found near the base of the deposit; the central Texas culture occurs in the upper part but may likewise extend to the lower levels. The extinct mammals of the formation include mammoth, mastodon, horse, bison, camel, dire wolf, peccary, armadillo, glyptodon, and ground sloth. There are also some extinct turtles of which the species have not been determined.

Since deposition of the terrace, regional uplift has rejuvenated the streams which have now become intrenched in the Berclair terrace deposits. Due to this uplift the present streams have a steeper gradient than the earlier streams. On stratigraphic evidence the Berclair terrace deposits are shown to be the upstream equivalent of the Beaumont formation, probably of Lower Beaumont age. The correlation, as indicated by the vertebrate fossils, is with the Melbourne formation of Florida and almost, if not exactly, with the Tedford bone bed of San Patricio County, Texas. The paleontologic and stratigraphic evidence indicates that the formation and the included artifacts and fossils are Pleistocene.

The fact that man inhabited these valleys during the Pleistocene implies, consistent with other evidence, that he had then attained a wide distribution on the continent. The varied and specialized cultural development of the Mission River valley inhabitants suggests that this occurrence does not represent the earliest occurrence of man in North America. The time of arrival of man on the continent is yet to be determined.

INTRODUCTION

During the past two years artifacts have been found associated with extinct vertebrates at several localities in Bee and Goliad counties in the Mission River drainage basin in the Coastal Plain region of Texas. The original discovery was made at a locality on the E. H. Buckner ranch on Blanco Creek about 1⅘ miles upstream from the Beeville-Goliad road crossing.[1] Permission to excavate at this locality was

[1] This locality may be reached as follows: From Beeville follow Beeville-Goliad road, Highway 96, east 10½ miles, turn north across railroad into the E. H. Buckner ranch. Continue north-northwest on ranch road 1½ miles to Blanco Creek. Locality in right bank of creek. The usage right and left as applied to the creek bank in this paper is in accordance with the definition in

generously given by the owner, Mr. E. H. Buckner, of Houston, Texas. Acknowledgment for courtesies extended is made also to H. Snedal, Pryor Lucas, J. J. O'Brien, Thomas Heard, and S. P. Farish on whose properties excavations have been made.

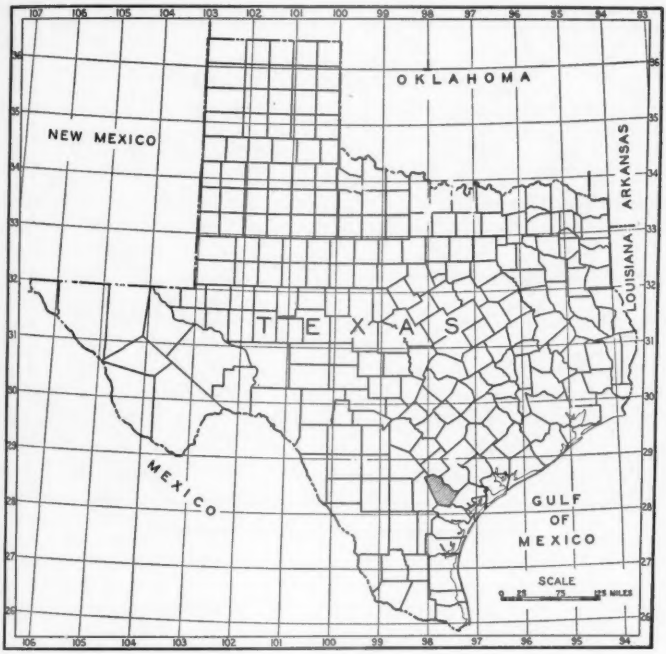


FIGURE 1.—*Index map of Texas*
Bee County indicated by shading.

Notice of the occurrence of fossils at the Buckner locality was given to the writer by Mr. and Mrs. Frank Daugherty, of Houston, Texas, in 1936. Preliminary explorations were made in February and March 1938. Extensive excavations begun in November 1938 are still in progress. In immediate charge of excavations were Glen Evans, November 1938 to May 1939; Adolph Witte, May to October 1939; and Nolan McWhirter, since October 1939. Invertebrate fossils are being identified

Webster's International Dictionary, 1926, p. 1231. "Left bank of a river, that which is on the left hand of a person whose face is turned downstream."

Assistance in the preparation of these materials was furnished by the personnel of Work Projects Administration Official Project No. 665-66-3-233.

by Horace G. Richards. W. N. McAnulty, and Joseph T. Gregory have aided the writer in identifying vertebrate fossils. W. Armstrong Price has given helpful suggestions on the geology of the Beaumont formation. The writer is greatly indebted to these gentlemen and to the Work

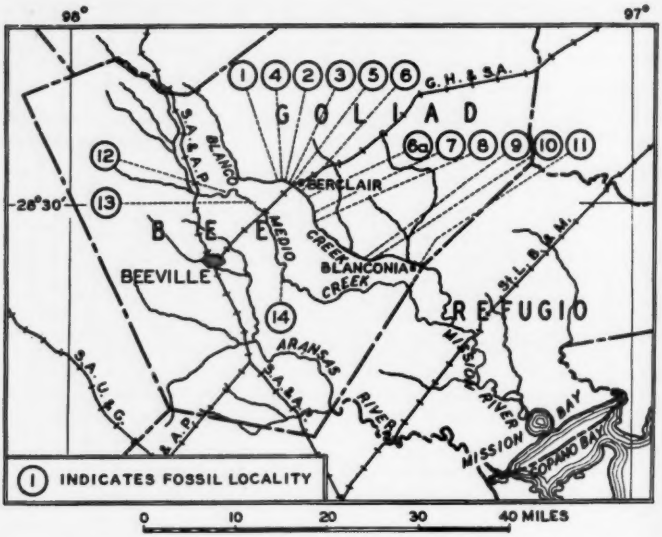


FIGURE 2.—*Map of Mission River drainage system and index to fossil localities 1 to 14*

Blanco Creek, on which are found localities 1 to 11, forms the boundary between Bee and Goliad counties; localities on left bank of stream are in Goliad County.

Projects Administration and The University of Texas by whom the explorations were made possible.

The geologic section exposed in the bed and sides of Blanco Creek at the Buckner locality, Site 1 (Fig. 2), consists of the Pliocene Goliad formation overlain unconformably by Pleistocene stream terrace deposits. Both contain vertebrate fossils. The Pliocene fossils, which are older than and not associated with the artifacts, will be described elsewhere.

Some flint flakes apparently of human handiwork had been obtained in the terrace deposits in January 1939 and, on February 8, D. L. Garner found an artifact at the base of the Pleistocene at a depth of 15 feet 10 inches. The find was immediately verified by Glen Evans, and on February 9 the writer visited the locality. The artifact at that time had been removed from the matrix, but fortunately the mould was

preserved. The artifact fitted the mould perfectly even to the details of chipping. After hardening the matrix with cementing solution, the mould was removed, thus preserving evidence that the artifact was imbedded at the base of the terrace deposit. Subsequent excavating at this and other localities resulted in the recovery of the fossils and artifacts described in this paper which are in the collections of The University of Texas.

INDEX TO SITES

Following is a list of sites from which collections have been made. It is quite certain that other sites will be developed. For a list of the Pleistocene fossils of each locality, the reader is referred to Table 1.

Site 1. Right bluff of Blanco Creek 9350 feet upstream from Beeville-Goliad public road crossing, Highway 96. Fossils and artifacts in the Pleistocene and vertebrate fossils in the Pliocene.

Site 2. Right bluff of Blanco Creek 4100 feet upstream from bridge on Beeville-Goliad road. *Parelephas columbi.*

Site 3. Right bluff of Blanco Creek about 1700 feet upstream from bridge on Beeville-Goliad road. Fossils and worked flint.

Site 4. Left bluff of Blanco Creek about 6600 feet upstream from bridge on Beeville-Goliad highway. *Paralephas columbi, Equus fraternus,* and *Bison* sp.

Site 5. Cut at east side of Beeville-Goliad road at bridge across Blanco Creek. *Parelephas columbi.*

Site 6. Right bluff of Blanco Creek 14,200 feet downstream from bridge on Beeville-Goliad road on J. J. O'Brien ranch, 600 feet upstream from confluence of Miller and Blanco creeks. Fossils and worked flint.

Site 6a. On left bank of Blanco Creek 0.5 mile downstream from Site 6 on Pryor Lucas ranch. Skull of *Equus fraternus* and other fossils.

Site 7. Left bluff of Blanco Creek about 5 miles southeast of Berclair on Pryor Lucas ranch. *Equus complicatus* and artifacts.

Site 8. Right bluff of Blanco Creek about 6 miles southeast of Berclair on Heard ranch. *Parelephas columbi* and *Equus complicatus.*

Site 9. Right bluff of Blanco Creek, 3 miles upstream from Blanconia. Worked flint.

Site 10. Right bluff of Blanco Creek, 2.25 miles upstream from Blanconia bridge on Fox ranch. *Parelephas columbi,* poorly preserved and not collected.

Site 11. Left bluff of Blanco Creek, 0.75 of a mile downstream from the Blanconia bridge. *Platygonus* sp.

Site 12. Left bluff of Boggy Creek, a tributary of Medio Creek, on the H. Snedal ranch. *Parelephas columbi, Mastodon americanus.*

Site 13. Left bluff of Medio Creek, 2.5 miles above crossing of Highway 96 on S. P. Farish ranch. Fossils and artifacts.

Site 13a. On small tributary of Medio Creek approximately 0.5 mile from Site 13. *Parelephas columbi.*

Site 14. On Medio Creek, Fox ranch, about 10 miles downstream from Site 13. *Parelephas columbi.*

FOSSILS

GENERAL STATEMENT

The formation in which the artifacts and fossils are found is a terrace of the Mission River drainage system. The town of Berclair is located near and partly on this terrace, and the terrace is here designated the Berclair terrace of the Mission River drainage system of which Blanco Creek is a part. The other principal tributary of Mission River is Medio Creek. Fossils are found in the terrace deposits to within a few feet of the top, their absence near the soil line being due probably merely to dissolving action of soil waters.

PRIMATES

The presence of man in these deposits is indicated by objects made of stone and silicified wood and by camp sites and hearths. Man-made objects have been obtained from the formation at Sites 1, 3, 6, 7, 9, and 13. These are described in the section on artifacts.

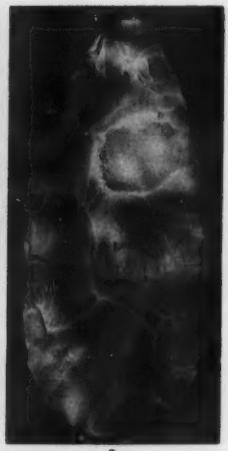
PROBOSCIDEANS

The proboscideans obtained from this formation include elephant and mastodon. The most abundant Pleistocene vertebrate fossil is the Columbian elephant, *Parelephas columbi* (Falconer). A tooth of this species, No. 30838-1, was found at Site 1 in the basal part of the formation at the same level as and near some of the artifacts. At Site 2 a tooth and scapula were obtained from the terrace deposits. At Site 3 two upper molars and a femur were found about 3 feet above the base of the deposit. The molars were still in position lying side by side. The skull, however, had disintegrated to such an extent that it could not be preserved. Two additional molars were found at this site within about 7.5 feet of the top of the terrace. With these molars were several bones including scapula, limb bones, vertebrae, and ribs. The badly disintegrated bones were not collected. The cut into the terrace deposits at the bridge across Blanco Creek, Site 5, yielded a tooth of this species. A tooth was found also in the upper part of the terrace deposit on the Snedal ranch, Site 12. One upper and two lower molars and bones of the skeleton were found at Site 6. Proboscidean bones, probably of this elephant, were found at Sites 4 and 10. The large teeth of this elephant have 19 or 20 plates; the smaller tooth found at Site 1 has about 14 plates. The plates are of medium size, counting 6, 7, or 8 per 100 mm.

A tooth from Site 6a in which the plates count 5 per 100 mm. is apparently to be referred to *Archidiskodon imperator* (Leidy).

1

2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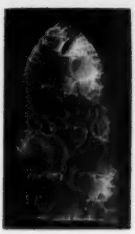
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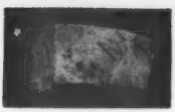
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ARTIFACTS

(1-3) Upper horizon; (4-9) Lower horizon

FIGURE 1. PIT AT SITE 1

FIGURE 2. EQUUS FRATERNUS
x ⅛

FIGURE 3. GLYPTODON PETALIFERUS
x ⅛

PLEISTOCENE FOSSILS

The American mastodon, *Mastodon americanus* (Kerr), is represented by a considerable part of a skeleton, including skull, tusks, lower jaws, vertebrae, ribs, and limb bones found at Site 12. The skull including lower jaws is exhibited at the Texas Memorial Museum, Austin. A milk molar and a cone from an adult molar found at Site 1 are referred to this species.

UNGULATES

The ungulates obtained from this formation are horse, bison, camel, deer, and peccary. Of these the horse, genus *Equus*, represented by three species, is the most abundant.

A large horse, apparently the giant Texas horse *Equus giganteus* Gidley, is represented at Site 1 by an upper right molar. In crenulations of the enamel, the tooth agrees closely with the type of the species which the writer has examined in the Cope Collection at The American Museum of Natural History in New York. The antero-posterior measurement, 41 mm., is essentially the same as that of the type. On the other hand, the transverse measurement, 30 or 35 mm., is less than that of the type. The type is a molar tooth recorded merely as from southwest Texas. However, the notes which accompany the specimen indicate that this tooth is part of an early collection made by William Taylor. From other sources (Wilson, 1890) it is known that a William Taylor lived in San Diego, Duval County, Texas, and made collections of fossils on San Diego Creek about 1888. It is believed, therefore, that the type locality of *Equus giganteus* is on San Diego Creek, Duval County, Texas, which is only about 70 miles from the Beeville locality. It is noteworthy that Taylor reports artifacts associated with the fossils collected by him near San Diego.

A horse, apparently *E. complicatus* Leidy, is represented by a right upper molar from Site 1, a broken right Pm3 from Site 3, a right upper Pm2 and a lower molar from Site 7, and several teeth from Site 8. Measurements of Pm2 are as follows: antero-posterior 40 mm., transverse 27 mm. The size of the tooth and the crenulations of the enamel agree closely with Pm2 of a skull from Henderson County referred to *E. complicatus*.

A horse smaller than *Equus complicatus* is represented at Site 1 by a left upper molar, five lower molars, and a right upper molar from Site 6, and a skull from Site 6a. Several lower molars probably of the same species have been obtained from Site 3 and parts of lower jaws from Sites 4 and 6. One upper and two lower molars were found in the stream bed. The measurements of the upper molar are: antero-posterior 26 to 27 mm., transverse 21 to 24 mm. The enamel surrounding the lakes in some teeth

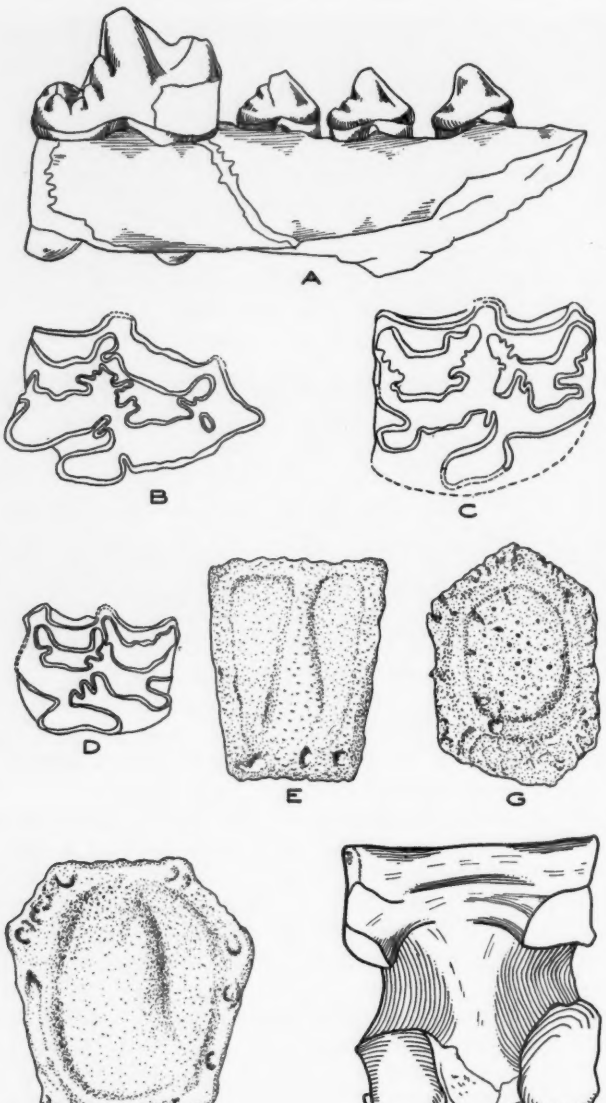

FIGURE 3.—*Pleistocene fossils*

(A) *Aenocyon ayersi*; (B) *Equus complicatus*; (C) *E. giganteus*; (D) *E. fraternus*; (E, F) *Holmesina septentrionalis*; (G) *Glyptodon* sp.; (H) ground sloth, genus indet. Natural size.

shows but few plications, being in this respect much simpler than in typical individuals of *Equus fraternus* Leidy. Notwithstanding these differences, these teeth are for the present referred to *E. fraternus*. In the skull the measurement from the front of Pm2 to the front of incisor is 142 mm. This same interval in four modern horses was found to range from 160 to 185 mm., the average being 167 mm. On the other hand, the width of the muzzle back of the incisors in the fossil skull is 82 mm., as compared to minimum 69, maximum 73, in the same four modern skulls. The incisors in the fossil, in keeping with the stoutness of the skull, are somewhat larger than those of the modern horse. The enamel folds in the teeth in this skull (Pl. 2, fig. 2) are much like those of the type of *E. fraternus*. The type specimen, which is in the American Museum of Natural History, is from Charleston, South Carolina. O. P. Hay (1913) has established a species, *Equus leidyi*, using as type several molar teeth, contained in the collections of Wagner Free Institute of Science at Philadelphia, from Peace Creek, Florida, previously referred to *E. fraternus*. The writer has compared the types of *Equus leidyi* with the type of *E. fraternus* and is doubtful if *Equus leidyi* is a valid species. The tooth compared was that selected as type of the species by Gidley (No. 9200), not the type previously selected by Cope and rejected by Gidley.

Among fossils unidentified as to species are lower molars of *Equus* found with artifacts at Site 13 and incisors, canines, and footbones at several other localities.

A bison is represented from Site 1 by a tooth and an astragalus; from Site 3 by an astragalus, ulna, and radius; and by bones from Sites 4, 6, and 6a. The length of the radius from Site 3 is 390 mm., and that of the ulna 520 mm. The size of the bones and teeth indicates one of the large extinct species, the radius and ulna being appreciably larger than the same bones of *Bison bison*.

A camel, *Camelops* sp., is represented at Site 6 by three lower jaws and a foot bone. Part of a cannon bone found at Site 1 probably represents the same species.

A peccary, *Platygonus* sp., is represented by a tusk from Site 11.

A deer, genus *Odocoileus*, is represented in the collections from Sites 1 and 6.

CARNIVORES

Carnivores are rare in this formation although several carnivore species are known to have been present during Pleistocene time. The collections from Site 1 contain a part of a carnivore tooth, but it was not until June 1940, after more than 1½ years of continuous collecting, that an identifiable carnivore was obtained. The specimen found, a

lower jaw, belongs to the large Pleistocene wolf, *Aenocyon ayersi* (Sellards), known also from the Pleistocene of Vero, Florida, and from San Patricio County, Texas. This species differs from *Aenocyon dirus*

TABLE 1.—*Vertebrate fossils from Berclair terrace deposits*

Fossils	Sites														
	1	2	3	4	5	6	6a	7	8	9	10	11	12	13	13a	14
Homo, represented by artifacts	x		x			x		x		x				x		
*Parelephas columbi**	x	x	x	x	x	x			x		x		x		x	x
*Archidiskodom imperator?**							x									
*Mastodon americanus**	x												x			
*Equus giganteus**	x															
*E. complicatus**	x		x			x		x	x							
*E. fraternus**	x		x	x		x	x									
*Bison** sp.	x		x	x		x	x							x		
*Camelops** sp.	x					x	x									
*Platygonus** sp.												x				
Odocoileus sp.	x					x										
*Aenocyon ayersi**						x										
*Holmesina septentrionalis**	x		x													
Dasypus sp.						x										
*Glyptodon petaliferus**	x					x								x		
Ground sloth*, gen. indet.			x													
Ondatra zibethicus	x															
Sigmodon hispidus	x															
Lepus sp.	x															
Scalopus aquaticus texanus	x															
Bird, gen. indet.	x															
Lizard	x							x								
Alligator	x					x	x									
Turtles	x		x			x		x						x		
Snake indet.	x															

* Extinct species.

(Leidy), among other characters, by a more elongated muzzle and consequently more widely spaced premolars, as seen in Figure 3A.

The saber-tooth tiger also found at Vero and Ingleside has not yet been obtained from this deposit.

EDENTATES

The edentates are represented by two species of armadillo, a glyptodon, and a ground sloth.

One armadillo, *Holmesina* (*Chlamytherium*) *septentrionalis*, is represented by plates of the carapace found at Sites 1 and 3. The plates were obtained near the base of the deposits. Plates from a species of *Dasypus* have been found at Site 6. The genus *Glyptodon petaliferus* is present at Sites 1 and 13 as indicated by plates and at Site 6 by a lower jaw. A ground sloth, genus not determined, is represented by a segment from the sternum found at Site 3, depth 7 feet.

OTHER VERTEBRATES

The following additional vertebrates have been obtained from the terrace deposits: muskrat, *Ondatra* sp.; cotton rat, *Sigmodon* sp.; *Scalopus aquaticus*; *Lepus* sp.; bird, indeterminate; lizards; alligator; turtles. The turtles, although as yet undetermined, evidently include several extinct species and occur in abundance at several localities.

In Table 1 is shown the distribution of the vertebrate fossils by sites.

INVERTEBRATES

Dr. Horace G. Richards has identified the invertebrates obtained from Bee County and from deposits of approximately equal age in San Patricio County and has recognized the following land and fresh-water species:

	Bee County	San Patricio County
Bulimulus dealbatus Say	x	..
Polygyra texasianum Moric	x	x
Helicina orbiculata tropica 'Jan' Pfeiffer	x	x
Helisoma trivolvis Say	x	x
Physa conoidea Crosse and Fisher	x	..
Physa integra Haldeman (?)	..	x
Physa halei Lea	..	x
Uniomeris sp	x	..
Sphaerium sp	x	..
Gyraulus parvus Say	..	x

With regard to the fossils Dr. Richards (personal communication) reports:

"The list of species from the two localities is too small to permit any definite statements regarding age or climate. All the species are known to be living in Texas today. A similarity is observed between the localities in Bee and San Patricio counties in regard to their mollusk fauna and there is no reason to doubt their contemporaneity."

ARTIFACTS

GENERAL CONSIDERATIONS

The deposits which contain the artifacts and fossils are typical stream-laid sediments. As is usual in terrace deposits, the heavier and coarser

materials lie near the base of the formation and grade upward into finer materials. The deposition is irregular including lenses of coarse and fine materials and cross-bedded sands. At Site 1, the lower 4 or 5 feet contains considerable gravel with occasional sand lenses. The next 4 feet consists of sand faintly laminated, above which is chiefly silt with some fine sand and clay up to the soil level. The artifacts have been found at two levels: in the upper part of the formation, depth from surface 2 to 7.5 feet, and near the base of the formation, depth from surface 13 to 17 feet. Between these levels the deposits are barren. This may indicate merely that the conditions were unfavorable for camp sites and for the accumulation of fossils.

FREQUENCY OF OCCURRENCE OF ARTIFACTS AT SITE 1

The area excavated for artifacts and Pleistocene fossils at Site 1 is approximately 125 by 45 feet. The depth of the terrace deposits is from 15 to 17 feet. Hence the total terrace deposit removed at this site was about 3700 cubic yards, most of which was screened. About 200 relics were obtained indicating the presence of man, including artifacts, partially worked flints, rejects, chips, flakes, burnt rocks, and hearths. Most of these came from the lower or basal part of the deposit.

The ground plan (Fig. 4, B) shows that the artifacts and associated man-made objects at Site 1 were not uniformly distributed in the area excavated but tend to occur in groups either in camp sites, hearths, or at the place of chipping. Thus in the immediate vicinity of spear 68, the first artifact found, was a worked flint, No. 70, and near-by seven flint chips, apparently flaked at this locality from some larger piece not recovered. A broken rock, No. 84, but not the one yielding the flakes, was found near-by. Not far removed is a worked flint, 86-12, accompanied by two worked but incomplete flints and one flake, a spear, 86-15, an incompleted worked flint, 86-11, and three flakes. These artifacts with the worked flint, No. 82, a serrate-edged flint, 83, and flakes, 86-6, make up a group of artifacts and chips somewhat separated from others. Among the chips one finds, in some instances, as in 86-6, several that come obviously from the same core, thus indicating that the flaking was done at this place and that the chips were not stream carried. Some of the artifacts, however, occur singly and probably were stream carried to their present position. The vertical and horizontal distributions of artifacts and fossils at Site 1 are indicated in Figure 4.

GEOLOGIC POSITION OF THE SEVERAL CULTURES

Folsom, Yuma, and stemmed projectile points, scrapers, gouges, blades, and other artifacts are found in the basal part of the Berclair

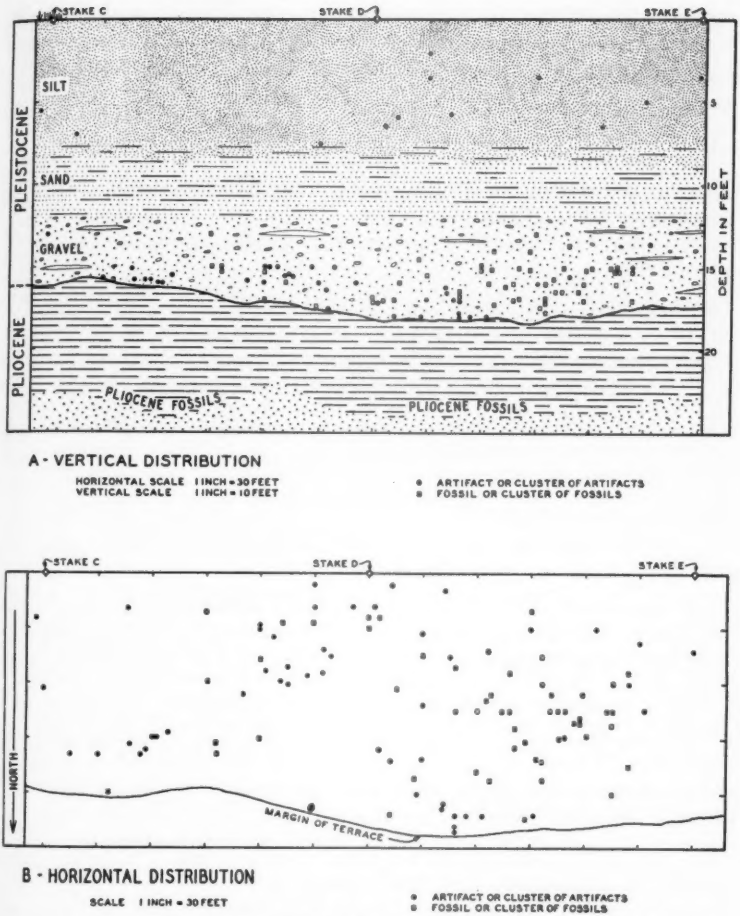

FIGURE 4.—*Vertical and horizontal distributions of artifacts and fossils at Site 1*
The first artifact found was located 42 ft. E, 33 N of stake D; depth 15.9 ft.

terrace and evidently are as old as the oldest part of this formation. There is evidence, also, of workshop activity at this level. In the upper part of the formation is found a gouge identical, according to Campbell, with the Clear Fork gouge described originally from the Abilene region. One example of this, No. 116-4, is reported from the basal part of the formation. Aside from this one occurrence the artifacts thus far

obtained from the upper part of the formation differ in some respects from those of the lower part below the sterile zone. The several cultures are sufficiently nearly contemporaneous to fall within the same geologic formation. They may represent either successive cultures or only successive habitation by different peoples or tribes. Folsom and Yuma cultures are probably not the oldest known cultures in America. Harrington (1938) and Hibben (1940) have reported artifacts stratigraphically below Folsom culture.

The artifacts of this locality have been studied by T. N. Campbell, of the Department of Anthropology of The University of Texas. His report follows. The stratigraphic position of the formation holding the artifacts is subsequently discussed. In order to determine the relation of these terrace deposits to the Pleistocene formations of the Gulf Coast, a traverse and line of levels were made downstream about 21 miles from Site 1. The report on this traverse by Glen L. Evans, who was in charge, follows the report on the artifacts.

NOTES ON ARTIFACTS

BY T. N. CAMPBELL

GENERAL STATEMENT

In this report only the more diagnostic artifacts and objects are described. All locations given for artifacts refer to the vertical and horizontal distribution charts of Figure 4.

SITE 1, UPPER HORIZON: DEPTH 2 TO 7.5 FEET

PROJECTILE POINT: Concave base, parallel-sided stem, rounded shoulders, edges of blade almost straight. Workmanship poor, with one face of the blade much better worked than the other. Distal end shows thermal fracturing, indicating damage by fire. No. 88-1; location 10 ft. E, 6 N of stake D; depth 7.5 ft. (Pl. 1, fig. 1).

GOUGES OR CONCAVE-BASE CORE SCRAPERS: This is the Clear Fork gouge of Ray (1929; 1934; 1938) and the concave-base core scraper of Sayles (1935). This type may be described as triangular in outline, with a straight base and edges that curve gently to a point. The base has a marked bevel. The amount of beveling varies, and within the individual specimen the beveling is usually more extensive in the central portion of the base, so that the edge of the base, when viewed from below (along the longitudinal axis), is curved; hence Sayles' term concave-base core scraper. The transverse cross section may be either plano-convex or bi-convex, depending upon whether chipping has been done on one or both sides. These gouges are made from thick flakes and seem to be retouched by the percussion technique. Three specimens occur in this series as follows: (1) Bi-convex in transverse cross section; chipped on both faces. This is the only gouge which shows notable concave-base design. (2) Plano-convex, chipped only on the convex face. Base very slightly concave. The base slants, *i.e.*, forms an acute angle with one side, an obtuse angle with the other. (3) Plano-convex; long, slender, curving. This differs from the

other two specimens in that the base, though beveled, is perfectly straight (Pl. 1, fig. 2). Nos. 88-2, 3, and 4; location and depth same as No. 88-1.

Another gouge, bi-convex in transverse cross section, pointed end broken, reported to come from depth of 17 feet, is the only gouge of this kind from the lower horizon. Since there is doubt about this specimen having been found *in situ*, it is placed with the material from the upper horizon. No. 116-4.

KNIFE: Leaf-shaped, pointed at one end, convex base. Workmanship fair. No. 88-5; location and depth same as No. 88-1 (Pl. 1, fig. 3).

BLADES: Crude, made of silicified wood. Leaf-shaped, with slightly convex base The base and one side are worked to a continuous cutting edge. The base suggests use as a gouge, the worked edge for scraping purposes. No. 88-6; location and depth same as No. 88-1.

Thick, roughly rectangular in outline. One end incompletely chipped, with some of the cortex visible; opposite end thin, suggesting use as a gouge. No. 98-1; location 30 ft. E, 10 N of E; depth 3.5 ft.

HAND AXE: Made from a small nodule fragment. Very short blade set at right angles to the thickest portion of the butt. Edge of blade broadly convex. This specimen could also have served as an adze or a scraper, but it seems to fall within the range of the well-known Texas hand-axe. No. 98-12; location 58 ft. E, 32 N of E; depth 6.5 ft.

CHARRED MUD-DAUBER NESTS: Six fragments of mud-dauber nest. Fire-baked (some parts fired to pinkish color, others blackened). No. 88-7; location 10 ft. E, 6 N of D; in hearth at depth 7.5 ft. Two possible interpretations, evaluated in order of naming: (1) attached to firewood; (2) larvae baked and eaten.

SITE 1, LOWER HORIZON: DEPTH 13 TO 18 FEET

PROJECTILE POINTS: Basal fragment of a Folsom point, probably the long variety. Channel flake removed from both faces. Edges and base appear to have been ground. No. 86-10; location 44.6 ft. E, 6.3 N of D; depth 15.1 ft. (Pl. 1, fig. 8).

Stemmed Yuma type (part of stem missing). Shows characteristic Yuma flaking, *i.e.*, parallel flake scars, diagonally directed across face of blade. Edges of stem seem to have been ground. No. 86-2; location 17.5 ft. E, 11.6 N of D; depth 15 ft. (Pl. 1, fig. 5).

Distal part of a small Yuma point. Very small and thin and shows the characteristic Yuma flaking. Such points are not common elsewhere but are known to occur along with the larger Yuma points. No. 86-16; location 23.3 ft. E, 22.1 N of D; depth 15.6 ft. (Pl. 1, fig. 7).

Stemless projectile point, lozenge-shaped, with concave base. Some grinding of the edges near the base. Typologically this would appear to be transitional between Folsom and the later Texas stemmed points. It resembles points shown by Ray in his Clear Fork culture. However, it is not uncommon in other central Texas cultures. No. 86-15; location 60.6 ft. E, 20.9 N of D; depth 13 ft. (Pl. 1, fig. 4).

Two stemmed projectile points, both of the same general pattern: straight base, expanding stem, sloping shoulders. This type is often referred to as side notched (broad side notches forming the stem). No. 68; location 42 ft. E, 33 N of D; depth 15.9 ft. No. 86-13; location 39.4 ft. E, 29.7 N of D; depth 16 ft. (Pl. 1, fig. 6).

GOUGES: Four specimens that seem to be variations of the same type. This type is not to be confused with the Clear Fork gouge of Ray. Each of these artifacts has a slightly beveled edge at one end, such as would serve admirably for gouging purposes. All are broadly oval in outline and have been worked on both faces. No.

86-7; location 15.9 ft. E, 19.6 N of D; depth 15.5 ft. No. 116-1; location 51 ft. E, 40 N of E; depth 18 ft. No. 116-3; location 56 ft. E, 34 N of E; depth 18 ft. No. 116-5; location 44 ft. E, 44 N of E; depth 18 ft.

KNIVES OR BLADES: Oval blade, crudely chipped by percussion technique. One face is more convex than the other, with one end somewhat beveled, so that the specimen has the general appearance of a snub-nosed scraper. No. 86-3; location 15 ft. E, 17.1 N of D; depth 15.5 ft.

Small blade or knife, oval in shape, fashioned from a flake. This seems to fall within the range of leaf-shaped blades or knives with convex bases. No. 86-8; location 15.2 ft. E, 20 N of D; depth 15.3 ft.

SCRAPERS: Circular scraper, retouched around three-fourths of its circumference to give a scraping edge. The flat face has some chipping; the convex face rises to a peak. No. 82; location 44 ft. E, 31 N of D; depth 15.7 ft.

Combination blade and concave scraper (spokeshave), oval in shape. One clearly marked concave scraping edge near one point, a less well marked one near the other point and on the opposite edge. It looks as though a blade had later been made into this sort of scraper. This is not a type in any known cultural complex in Texas. No. 86-5; location 13.5 ft. E, 18.1 N of D; depth 16.3 ft.

Side scraper made from an irregularly shaped flake, with one edge rather steeply retouched. No. 116-7; location 42 ft. E, 44 N of E; depth 18 ft.

AXE OR ADZE: An unusual specimen. Notches on edges indicate hafting, either as an axe or as an adze (transversely), or possibly even as a scraper. The edge of the blade shows some evidences of usage. No. 70; location 42 ft. E, 33 N of D; depth 15.9 ft.

MUD-DAUBER NEST: Fire-baked. It is of interest that quite a number of these specimens occur at Site 1. No. 125; location 50 ft. E, 33.7 N of E; depth 17 ft.

SITES 3, 6, 7, 9, AND 13

FLAKES: A number of flakes appear, but only one seems to be the product of human flint working. Site 3. No. 104; from near base of terrace; depth 14 ft.

CORE: Core from which large flakes have been struck. Site 6. This could have served for chopping purposes, since there is one sharp edge, but this is not likely. No. 111; from near base of terrace; depth 16 ft.

PROJECTILE POINT: Basal part of small Yuma point. Site 7. Apparently the same type as No. 86-16 from Site 1. Shows characteristic Yuma flaking. No. 109; found not in place at the base of the bluff at Site 7 (Pl. 1, fig. 9). This artifact is referred to the lower horizon on the basis of its close resemblance to projectile point No. 86-16 (Pl. 1, fig. 7) which is known to come from the lower horizon.

FLAKE: Irregularly shaped flake, apparently the product of human flint working. Site 9. No clear evidence of use. No. 112; from the base of the terrace; depth 14 ft.

CONCAVE SCRAPER OR SPOKESHAVE: Small flake with concave scraping edge that shows some slight evidences of use. Site 13. No. 126-1; from near base of terrace.

FLAKES: Two flakes, one fairly large with two edges that seem to have been chipped through usage, the other small flake with no evidence of use. Site 13. Nos. 126-2 and 3; from near base of terrace.

COMMENT AND CONCLUSIONS

UPPER HORIZON: The artifacts from the upper strata at the Bee County site are considerably illuminated by comparison with the material from

the recently excavated Morhiss Mound n. .r Victoria, Texas. This stratified midden shows clear evidence of long occupation, with at least three cultures represented. The site is located on a terrace of Guadalupe River and is only about 50 miles east of the Bee County site. Mr. W. A. Duffen, Archaeologist and WPA Project Superintendent of the South Texas Unit, State-Wide Archaeological Survey, The University of Texas, was in charge of excavation at the Morhiss Mound and is now writing a report. He examined the Bee County materials and made the following significant observations:

"The Bee County artifacts from the upper horizon are clearly identifiable with the earliest material in the Morhiss midden. The projectile point, No. 88-1, occurs as a type in the Morhiss midden, where it is confined to the lower third of the midden deposits. Gouges or concave-base core scrapers of both varieties, plano-convex and bi-convex in cross section, as in Nos. 88-3, 4, and 5, occur numerously at the base of the Morhiss midden. Very few are found in the upper layers. Hand axes occur at all levels. They are rare at the bottom, however, with frequency increasing as one proceeds upward. A knife, identical in outline with the leaf-shaped specimen from Bee County, No. 88-6, was found below the midden deposits in an upper stratum of the river terrace. The foot bone of a camel was found in the terrace deposits in a stratum immediately above the knife."

Inasmuch as the Morhiss midden site was occupied over a considerable period of time by several cultural groups, the lowest material would probably represent one of the early cultures in the Coastal region of Texas. Since the Bee County upper material is identifiable with the lowest Morhiss midden material, we have here the beginnings of a good relative chronology for the Texas coast.

Considered in the light of the preceding, it would appear that the upper material from the Bee County site is early in the central Texas series. Its importance lies in its stratigraphic relationship to the Folsom and Yuma material below and also in its identity with the earliest culture represented at the Morhiss midden.

Lower Horizon: Examination of the artifacts from the lower horizon at the Beeville site brings out at least two significant points:

(1) Folsom and Yuma material is unmistakably present. This site in Bee County seems to be the southernmost Folsom site, and its discovery extends the distribution of Folsom sites much farther south than heretofore known. The blades and scrapers of this series, in the light of the Lindenmeier finds, might be expected to go with the Folsom and Yuma material, but the same cannot be said of the remainder of the artifacts, especially the axe (or adze) and the stemmed projectile points. The axe or adze is an unusual specimen and does not appear elsewhere as a type.

(2) It is somewhat surprising to find stemmed projectile points associated with Folsom and Yuma points. This association is of considerable

importance in connection with the dating of the other Texas cultures that are generally regarded as early. It would appear that the Folsom culture and the early cultures of central and coastal Texas overlap in time.

NOTES ON TERRACE DEPOSITS

BY GLEN L. EVANS

GENERAL CONSIDERATIONS

Blanco Creek, one of the principal tributaries of the Mission River drainage system, heads in the southern part of Karnes County, Texas, and flows southeastward forming the boundary between Bee and Goliad counties. Medio Creek heads near the Karnes-Bee County line and approximately parallels Blanco Creek through Bee County. In Refugio County the two streams unite to form Mission River which flows into Mission Bay (Fig. 2). The streams flow across a low and gently dipping coastal plain of emergence.

Two periods of stream deposition in this drainage system are represented in the main valley and in the tributary valleys. In the first period the Berclair terrace was formed in the upper or older valley. During the second period was formed a lower valley and terrace. For a part of the course the valleys are independent, but through the middle reaches of the stream they exist in a "valley-within-valley" relationship (Fig. 5). The upper valley starts near the head of the present stream and terminates in the vicinity of Blanconia in southern Bee County, some 20 miles inland from Mission Bay. The lower valley becomes intrenched within the older valley about 10 miles below the stream's head and terminates at Mission Bay.

THE OLDER VALLEY

The greater part of the older valley and its principal tributary valleys was formed in and rests on the Goliad formation, but the lower reaches of the valley extend across the outcrop belt of the Lissie. Near its head the older valley is entrenched 50 or 60 feet below the general level of the adjacent divides. Downstream intrenchment decreases progressively until at Blanconia the valley walls are no more than a few feet high. The older valley is approximately 30 miles long; the width, about 2000 feet near the head, gradually increases to more than a mile in the lower reaches. The valley walls are mature, with moderately gentle slopes, usually well covered by grass and brush. The bedrock of the valley contains channels and other minor irregularities but is otherwise quite flat. The width and flatness of the valley floor are evidence that the ancestral streams continued for a long period to widen all parts of their valleys by lateral migration of the channel after it became graded or

nearly so. The principal tributaries, such as Indian Creek, Trout Creek, Miller Creek, and Maja Arroyo, have similarly developed smaller valleys.

BERCLAIR TERRACE

The older valley is filled by a well-developed ancient flood-plain or valley-fill terrace deposit, which has been named the Berclair terrace. This deposit was formed late in the first erosional cycle of the streams. The terrace extends upstream practically to the head of the streams. The deposit varies in thickness from an average of 10 or 12 feet in the upper reaches of the valley to 20 or 25 feet in the lower reaches. The terrace widens and thickens downstream and ultimately spreads widely. In so doing it loses its identity as a stream terrace and becomes a part of the Coastal Plain formation. Where the terrace materials begin to spread they thin markedly. The streams appear to have flowed into a partially filled lagoon or onto a wide salt flat which must have been at or very near sea level of that time but which is about 70 or 80 feet above the present sea level. Seaward these deposits may grade into typical Beaumont facies or may be an intercalated sand member in the Beaumont beds or may be confined in a cut-off lagoon which was never resubmerged.

The composition of the terrace ranges from light-gray to dark-gray sand, gravel, silt, and alluvial clay derived from the later Tertiary rocks of the region, particularly from the Goliad formation. Secondary calcium carbonate in the form of caliche in varying concentrations is universal. In a typical section, the cross-bedded gravels appear at the base of the deposit, poorly stratified sands in the middle, and the silts and clays at the top. The percentage of gravel and coarse sand decreases in the lower reaches of the valley. These materials are sufficiently compacted and consolidated by caliche for vertical bluffs to form on the side of the channel against which the stream impinges. The fine sediments at the top of the deposit are usually more firmly cemented than are the coarser sediments.

The terrace in general has a broad flat surface capped by a mature soil which supports a dense covering of the typical coastal varieties of brush and trees. In places, particularly in the middle and lower portions of the valley, old channel scars or traces of filled channels are present. Low ridges of sand, presumably remnants of natural levees, parallel the channels on both sides. Where meander-cut bluffs of Blanco and Medio creeks expose these filled channels they are seen to be too shallow to cut through the terrace deposit and are filled with humus-stained sand. These channel scars are not related to tributary streams and do not appear to be cut-off meanders of the present Blanco and Medio

creeks. It is believed that these shallow channels were formed by intermittent run-off after the upper valley was filled and before rejuvenation had permitted the present channel to become permanently intrenched. A similar condition exists at present, although on a more limited scale, at the extreme head of the upper valley where headward erosion of the main channel has not yet reached, and the run-off is carried in shallow

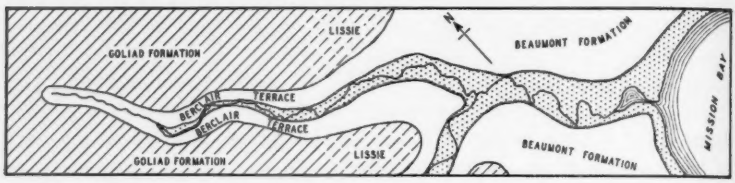

FIGURE 5.—*Diagrammatic representation of the relation of the valleys of Blanco Creek*
Showing relation of the older valley, Berclair terrace, to the Coastal Plain formations and to the later valley and low terrace of Blanco Creek.

discontinuous channels. Except in the unexcavated valley near its headwaters, the present channel cuts into the bed rock. The amount of cutting into the bed rock increases from a few feet in the upper reaches of the streams to a depth downstream of 38 or 40 feet.

Table 2 shows average width, thickness, and gradient of the Berclair terrace in reference to the present stream channel. The terrace thickens and widens progressively downstream for some distance and thins in the last four measurements where the width could not be ascertained because the deposit spreads to an unknown distance. All distances between points of measurement are along a straight line.

THE YOUNGER VALLEY

After the formation of the older valley the Coastal Plain gradually emerged. During emergence, Blanco and Medio creeks maintained their drainage to the bay across the gradually widening plain, increased their length by about 20 miles, and united to form Mission River. The drainage system became rejuvenated in a second erosional cycle, and a younger valley and flood plain or low terrace formed.

The younger valley formed first along the seaward extension of the drainage system between the termination of the older valley and the coast but has since extended by headward erosion for a considerable distance into the floor of the older valley. In these upper reaches it has cut through the old valley fill and well into the underlying Goliad and Lissie formations. In its uppermost reaches, the recent valley has a width of only 400 to 500 feet and is intrenched to a depth of about 25

feet below the surface of the old valley. This part of the valley is still being eroded. The width and depth increase downstream to 1270 feet and 38 feet respectively at Blanconia, 2100 feet and 55 feet at a point about midway between Blanconia and Refugio, and 2600 feet

TABLE 2.—*Width, thickness, and gradient of Berclair terrace*

Place measured	Width (Feet)	Thickness (Feet)	Height of base above stream bed (Feet)
1. East of Tuleta, 9½ miles below head of Blanco Creek	2000	10.5 to 12.5	2.5 to 3
2. Five miles below No. 1 and 1½ miles above highway bridge on Blanco Creek, west of Berclair, Buckner ranch	2800	18 to 21	3 to 4.5
3. At a pipeline across Blanco Creek on Lucas ranch, 5.4 miles below No. 2	3700	20.5	7
4. On Heard ranch 3.5 miles below No. 3	5250+	22.5	10
5. Blanconia bridge, north side of creek, 7 miles below No. 4	?	22.5	13
6. At first big bend in creek below mouth of Sarco Creek, 1.3 miles below No. 5	?	18.5	16.5
7. Refugio County, 2.2 miles below No. 6	?	11	25
8. Refugio County, 5 miles below Blanconia bridge	?	8 to 14	38

wide at Refugio. Below Refugio the valley widens to a mile or more, but its actual depth has not been ascertained. The floor of the lowermost reaches of the valley lies below the present sea level, as the stream channel is drowned to a distance of 4 or 5 miles above its mouth. This apparently indicates depression to present level following maximum uplift. The lower reaches of the valley, which is entrenched in the Beaumont formation, has reached maturity, and the stream is now here aggrading its channel.

LOW TERRACE

A low terrace, the present flood plain, has been formed within and coastwards from the termination of the older valley. It extends from the upper reaches of its enclosing valley to Mission Bay. Near the bay it spreads out as a low flat bordering the shore and merges with other similarly spreading flood plains. All parts of the terrace are subject to overflow during flood, and consequently it is still in the process of building by accumulating flood sediments. The deposit consists mainly of humus-stained, medium- to coarse-grained sand with minor amounts

of gravel at its base. In its lower reaches, fine sands and silts replace the coarser-grained deposits.

In the uppermost reaches of its valley, the low terrace first appears as a narrow alluvial shelf lying on the convex side of the meanders and on

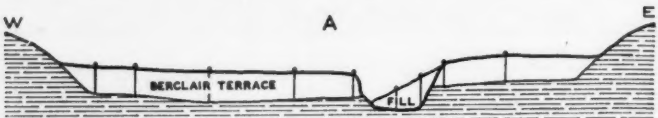

FIGURE 6.—*Cross section of valley and terraces of Blanco Creek* (A) at Site 1; (B) at Blanconia. Scale: horizontal, 1 inch = 1000 feet; vertical, 1 inch = 80 feet.

the slipoff slopes. It widens gradually downstream. The deposit thickens from an average of 14 to 16 feet in the upper reaches to more than 30 feet in the lower reaches. Below Refugio the terrace base lies below present sea level, and the actual thickness has not been determined.

COMPARISON OF BERCLAIR TERRACE WITH LOW TERRACE

Certain marked differences distinguish the Berclair terrace from the low terrace. The low terrace is an aggrading flood plain, all parts of which are subject to overflow by Blanco and Medio creeks, while only the extreme upstream part of the Berclair terrace is subject to flooding. The low terrace is longer and thicker while the Berclair terrace is wider. The Berclair terrace extends farther inland, and the low terrace extends farther seaward. The low terrace lies everywhere at lower levels than adjacent points of the Berclair terrace. The low terrace rests against a valley wall of the Berclair terrace. In the uppermost extremities it is 8 to 10 feet vertically below the Berclair terrace. The seaward slope of the recent valley is greater than that of the older valley. Hence the two valleys become separated by increasing vertical distances at successive downstream points.

The Berclair terrace is well dissected by tributary streams projecting laterally from the intrenching recent valley. The late terrace is crossed by very few tributary streams, and nowhere do they cut completely through the deposit to the underlying bedrock.

The basal gravels of the Berclair terrace do not contain subsurface water in quantity, and no seep springs occur along its dissected margins. This is to be expected because the surface is well drained by numerous tributaries and because any surface water that finds its way into the gravels soon escapes into the numerous channels which cut through the deposit into the underlying formation. Subsurface water is present in some quantity at the base of the low terrace throughout its well-developed area. Its surface is poorly drained, and the highly porous character of its sediments permits easy entry of surface waters. Also its base lies below the level of stream dissection so that in most places its water cannot readily escape by seep springs.

The difference in the character of sediments of the two terraces is pronounced. The Berclair terrace is composed of an important percentage of gravel and coarse sand, whereas the low terrace contains an unimportant percentage of gravel and is primarily slightly compacted humus-stained sand. The Berclair terrace is a light gray to gray and contains much secondarily deposited calcium carbonate, while the more recent terrace is characteristically dark gray and contains very little calcium carbonate. The Berclair is generally well compacted and to some extent consolidated by the infiltrated caliche so that it weathers into vertical bluffs, while the late terrace is ordinarily but slightly compacted and exhibits gentle slopes on its stream-weathered margins. The Berclair has a relatively flat surface and a thick mature soil supporting dense vegetation; the recent terrace is more undulating and has a poorly developed soil with comparatively sparse vegetation. Vertebrate fossils, common in the Berclair terrace, are rare in the more recent terrace.

SUMMARY

Blanco and Medio creeks came into existence in post-Pliocene time, as indicated by their intrenchment in the Goliad formation. In forming the older valleys the streams must have been eroding actively for a considerable period to remove the enormous amount of material necessary to the formation of the relatively wide and deep valleys. After the streams reached grade and could no longer deepen their valleys they continued for some time to scour laterally by migration of their meanders. During this widening much of the Berclair terrace was deposited. As a result of this period of lateral corrasion and aggradation, the entire valley floor and the floors of the tributary valley were mantled with a considerable thickness of alluvium; these are features of an old mature valley. The waters of the ancestral creeks spread widely and deposited fine sands and silts over low flats or a partly filled lagoon near sea level, these deposits being the downstream extension of the Berclair terrace.

GEOLOGIC AGE OF THE FORMATION CONTAINING THE ARTIFACTS AND FOSSILS

AGE OF BERCLAIR TERRACE AS INDICATED BY STRATIGRAPHIC POSITION

An important fact brought out in the report by Evans is that the Berclair terrace does not extend to the present coast but apparently merges with the Beaumont formation. Dr. W. Armstrong Price (personal communication), who has made an extended study of the Beaumont, is of the opinion that the Upper Beaumont lies offshore to the east and that the exposed part of the formation in this region is Lower Beaumont. If this be true, the terrace deposits cannot be later than latest Lower Beaumont or lower Upper Beaumont. The profile of the Pleistocene stream as compared to that of the present stream, shown by Figure 7, offers important evidence of correlation of the terrace with the Beaumont formation. These profiles show that in Pleistocene time when the valley was being filled the gradient of the stream in this part of its course was less than in the present stream which has been rejuvenated. The flattening of the Pleistocene stream profile approaching what apparently was then the coastal lagoon compares closely with the flattening of the profile of the present stream approaching present sea level at Mission Bay. In Table 4 the approximate position of this terrace is shown in relation to some other formations of the Gulf Coast region.

AGE OF BERCLAIR TERRACE AS INDICATED BY FOSSILS

The fossils of the Berclair terrace include mammals, birds, reptiles, and land and fresh-water invertebrates. The birds and reptiles are as yet too imperfectly studied to be of immediate value in determining age. As is well known, the invertebrate faunas of the late Pleistocene south of the glaciated areas are closely similar to the recent faunas of the same region. This has been proven for the marine invertebrates at Vero and Melbourne, Florida, where an extensive vertebrate fauna, including extinct species of mammals, birds, and reptiles, rests upon shell marls containing relatively few extinct species. In San Patricio County, Texas, an equally extensive vertebrate fauna overlies marine shell deposits with but few extinct forms and is in immediate association with land and fresh-water invertebrates mostly of recent species. It is expected, therefore, that the invertebrate fauna will be found to be nearly the same as the modern fauna. The mammals, on the contrary, have undergone great changes chiefly in the extinction of the larger species in relatively late geologic time. In Table 3 the mammals from the Berclair terrace are compared with those obtained from two other localities—Vero, Florida, and the Tedford pit at Ingleside, Texas. The mammals listed from Vero are from the Melbourne formation which overlies the Anastasia formation consisting of marine Pleistocene

shell marl and is overlain by the Van Valkenburg beds. A closely similar fauna has been obtained from this formation at Melbourne, Florida, by Gidley and Loomis (Hay, 1927, p. 273) and at Seminole Field, Florida, by Simpson (1930). At Vero and at Melbourne as well as in Bee County

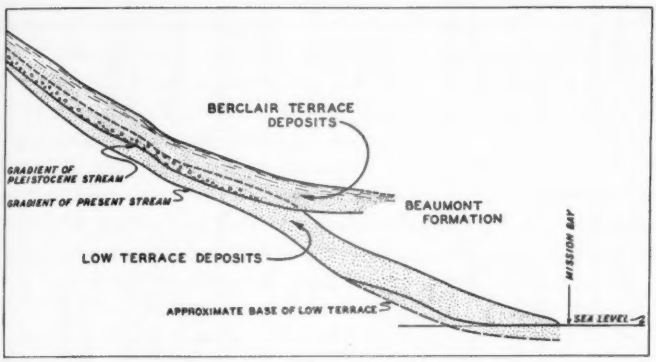

FIGURE 7.—*Profile of Blanco Creek*

Downstream from Site 1 of the Pleistocene stream that formed Berclair terrace and of the modern stream, Blanco Creek. Note difference in gradient of the Pleistocene and modern streams. Approximate scale: horizontal, 1 inch = 50,000 feet; vertical, 1 inch = 100 feet.

human relics have been found under conditions indicating that man was a part of this fauna.

Since the fauna at Ingleside, Texas, is closely similar to that of Berclair terrace it is important to determine the age of the Ingleside fauna. The Ingleside fossils are found in a filled pond several acres in extent resting on the Beaumont formation. The pond fill has a depth of from 7 to 9 feet. The section through the pond deposits is as follows: Soil, 0.5 to 1 foot; caliche, not invariably present, 1.5 to 2 feet; and yellow sand with lenses of white sand and thin clay laminae and in places nodules of bog manganese, 6 or 7 feet. Fossil bones and pond snails occur throughout the deposits below the soil level, the bones being most abundant near the base of the fill. One artifact, not in place, has been found in the caliche and sand hauled from the pit. Borings below the bottom of the pond fill show clay and sand strata with marine shells. The pond is surrounded by sand dunes. At one locality near the northeast margin of the pond where the caliche is absent two soil layers are separated by several feet of sand. In the lower soil layer in the margin of the sand dune was found a considerable part of the skeleton of an elephant. This and other considerations indicate that the dunes, which are quiescent and overgrown

TABLE 3.—*Comparison of the mammalian fauna of Berclair terrace of Mission River drainage system with that of the Melbourne formation at Vero, Florida, and of the Tedford pit, Ingleside, Texas*

Family	Berclair terrace	Vero, Florida (Melbourne formation)	Ingleside, Texas (Beaumont, Lower or Upper)
Hominidae	Artifacts	Artifacts and skeletal parts	Artifact
Elephantidae	*Parelephas columbi**	*Parelephas columbi**	*Parelephas columbi**
	*Archidiskodon imperator?**		
Mastodontidae	*Mastodon americanus**	*Mastodon americanus**	*Mastodon americanus**
Equidae	*Equus complicatus**	*Equus complicatus**	*Equus complicatus**
	*Equus fraternus**	*Equus leidyi**†	
	*Equus giganteus**	*Equus litoralis**	
Camelidae	*Camelops** sp.	*Camelops?** sp.	*Camelops** sp.
			*Tanupolama** sp.
Bovidae	*Bison** sp.	*Bison** sp.	*Bison antiquus**
Cervidae	*Odocoileus* sp.	*Odocoileus sellardsiae**	*Odocoileus virginianus*
Tayassuidae	*Platygonus** sp.	*Tayassu lenis**	
Canidae	*Aenocyon ayersi**	*Aenocyon ayersi**	*Aenocyon ayersi**
Dasypodidae	*Holmesina septentrionalis**	*Holmesina septentrionalis**	*Holmesina septentrionalis**
	*Dasypus** sp.	*Dasypus** sp.	
Glyptodontidae	*Glyptodon petaliferus**	*Glyptodon** sp.	*Glyptodon petaliferus**
Megatheridae	Ground sloth* indet.	*Megalonyx jeffersoni**	
Mylodontidae	?	*Mylodon harlani**	*Mylodon harlani**
Leporidae	*Lepus* (*Macrotolagus*) sp.		*Sylvilagus* sp.
Muridae	*Sigmodon hispidus*	*Sigmodon* sp.	
	Ondatra zibethicus	*Neofiber alleni*	
Talpidae	*Scalopus aquaticus texanus*		

* Extinct species.

† *Equus leidyi* Hay, the writer now believes, is a synonym of *E. fraternus* Leidy.

with timber and underbrush, are the same age as the pond and accumulated previous to the disappearance of the elephant and that both the dunes and the pond deposits date from the time when this dune was at the shore line of a bay or lagoon of the Gulf and was at sea level of that time. This conclusion is further supported by the presence of worn sea shells found in the bone bed such as could have been and apparently were thrown across the sand dunes by storm waves when the pond was immediately back of the sand dunes of the coast line. W. Armstrong Price (personal communication), after studying this locality, is of the opinion that the pond deposit is of late Lower Beaumont or early Upper Beaumont age.

It is seen from Table 3 that almost all the species of mammals found in the Berclair terrace deposits are present also in the Melbourne formation at Vero and in the Tedford pit at Ingleside. Vertebrate fossils are abundant at both the Vero and Ingleside localities. The following mammalian genera and species, not found in the Berclair terrace, have been found in the Melbourne formation at Vero. Extinct species are indicated by asterisk. *Hydrochoerus robustus,* Tapirus veroensis,* T. haysii?,* Smilodon (Trucifelis) floridana,* Vulpes palmaria,* Lutra canadensis, Procyon lotor, Odocoileus osceola?, Didelphis virginiana, Cryptotis floridana, Blarina brevicauda peninsulae.* A few additional species are recorded from this formation at Melbourne and at Seminole, Florida. The following species, not found in the Berclair terrace, have been obtained from the Ingleside bone bed: *Tapirus veroensis,* Cervus* * sp., *Smilodon* * sp., *Canis* sp., *Cynomys ludovicianus.*

Notwithstanding that the Berclair terrace has yielded a smaller fauna than have the other two localities, the almost complete agreement in genera and species among the fossils obtained indicates a very close if not exact correlation in age between the three localities. The gradual increase in the faunal list during the past 2 years of excavating indicates that additions may yet be made to the known fauna of the Berclair terrace.

The fauna supplemented by evidence as to stratigraphic position affords the basis for the tentative correlation given in Table 4 of some of the Pleistocene formations of the Gulf Coast region. Subsequent investigations may afford evidence for some adjustments in this proposed correlation. However, the writer is confident that in the main the correlation of Pleistocene formations as shown here is correct.

CONCLUSIONS

The artifacts found in the Berclair terrace of the Mission River drainage system include more than one cultural type. These cultures may

* Extinct species.
† *Equus leidyi* Hay, the writer now believes, is a synonym of *E. fraternus* Leidy.

be in part contemporaneous, but it is more probable that some difference exists in the age of the cultures. The Folsom and Yuma cultures are probably contemporaneous. Stemmed projectile points are found at this same level in the deposits. The Clear Fork gouge is present in the

TABLE 4.—*Tentative correlations*

VERO FLORIDA	INGLESIDE TEXAS	MISSION RIVER TEXAS
VAN VALKENBURG BEDS		LOW TERRACE
MELBOURNE BONE BED	ANCIENT SAND DUNES INGLESIDE BONE BED AND LOWER BEAUMONT CLAYS INCLUDING MARINE SHELL MARL	BERCLAIR TERRACE AND LOWER BEAUMONT CLAYS
ANASTASIA MARINE SHELL MARL		

latest culture found in this terrace. As valley fill proceeds slowly it follows that the artifacts of the basal part of the formation may be appreciably older in years than are those at a higher level.

The life history of the stream includes the following periods or stages: (1) development of the stream to approximately its present inland extent accompanied by downcutting essentially to grade level; (2) meandering and lateral erosion at grade level by which the valley was enlarged to its present width accompanied by valley fill to the present thickness, or nearly so, of the Berclair terrace deposits; (3) regional uplift resulting in rejuvenation of the drainage, renewed downcutting, and extension of the stream to the present Gulf Coast; (4) formation of the younger valley best developed in the lower reaches of the stream; (5) depression forming the present drowned valley of this stream.

The artifacts, hearths, and camp sites are evidence of man's occupation of the valley during stage No. 2. To measure the lapse of time in years since man's first known habitation here is extremely difficult. It is not known how long the filled valley may have remained essentially at grade level. It is not known what length of time is involved in the regional uplift of stage No. 3. Evidence though meager suggests that uplifts proceed slowly and that the time interval is to be counted in millenniums. Lastly there is the unknown interval of time required for the stream to intrench itself during or following the uplift and to cut to grade in its lower course and by lateral meandering establish a

younger valley which in places exceeds a mile in width, this having been followed by depression of the land surface with respect to the ocean level. Bryan and Ray (1939) have suggested that the Folsom culture, one of those present in the Berclair terrace, may be 25,000 years old, Antevs (1936) places the age at 12,000 to 13,000 years, and Roberts (1940) suggests 15,000 years as the time of first appearance of man in America. In view of the recorded geologic events since man occupied these stream valleys—valley fill, regional uplift, formation of a lower terrace and coastal depression—the largest of these estimates seems doubtfully adequate, and one is inclined to think of an interval of possibly two or three times 25,000 years.

The geologic age of the formation is definitely Pleistocene. This conclusion is established on stratigraphic evidence which shows that the terrace is the upstream equivalent of the Beaumont formation and probably represents the Lower Beaumont. The Pleistocene age is further indicated by the fauna in which the mammalian species are largely extinct. The correlation of the terrace deposits is with the Melbourne bone bed of Florida and with or slightly older than the Tedford bone bed at Ingleside, Texas. The climatic conditions may not have been greatly different from those of the present. The locality affords evidence of the presence of man in America in a comparatively advanced cultural stage in the latter part of the Pleistocene period.

Man's presence in the valleys of the Mission River drainage system during Pleistocene implies his presence at the same time over a much larger area, probably, consistent with other records, throughout most if not all of North and South America. Moreover, the Folsom, Yuma, and Clear Fork are specialized cultures. So far as known they are indigenous to North America, and if this is true it is not reasonable to assume that they represent the earliest Americans. The time of first arrival of man on the continent is yet to be determined.

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NEW PLIOCENE MASTODON

BY E. H. SELLARDS

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ABSTRACT

The paper contains description of a new Pliocene mastodon and a list of associated fossils constituting a new Pliocene fauna in the Goliad formation of Texas.

INTRODUCTION

Excavations made on the E. H. Buckner ranch on Blanco Creek about 12 miles east of Beeville, Bee County, Texas, during the past 2 years have brought to light a new Pliocene vertebrate fauna from the Goliad formation.[1] To reach the Pliocene it is necessary to remove from 15 to 17 feet of fossiliferous Pleistocene. The bone bed is 5 or 6 feet below the top of the Pliocene and hence is at a depth of about 22 feet from the surface. That fossiliferous Pliocene at this locality is overlain by fossiliferous Pleistocene may be merely a coincidence. On the other hand there is the possibility that a spring near-by, accounting for the accumulation of Pliocene fossils, continued into the Pleistocene. However, no spring is found at or near the locality at the present time. The excavations have been made by the Work Projects Administration and The University of Texas.

[1] Assistance in the preparation of these materials was furnished by the personnel of Works Projects Administration Official Project No. 665-66-3-233.

GNATHABELODON BUCKNERI N. SP.
(Figures 1-3)

The most abundant fossil in the Pliocene deposits is a new long-jawed mastodon of which 15 skulls of immature and adult animals have been

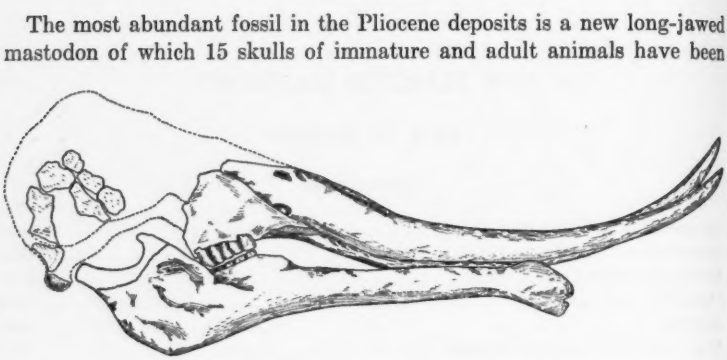

FIGURE 1.—*Side view of front part of skull*
Showing upcurved tusks and long lower jaws. No. 390. X1/20.

obtained. These 15 skulls and a proportionate number of other bones of the skeleton and many other fossils were taken from an excavation 50 by 200 feet.

The new mastodon has long lower jaws lacking incisors or tusks. At the tip the lower jaws are slightly widened, smooth on the upper side, and slightly bifid at the front. This part of the jaw was probably padlike in appearance, in this respect resembling the spoon-billed mastodon, *Megabelodon lulli* Barbour, from the Pliocene of Nebraska. The tusks of the upper jaws are well developed, measuring 5 or 6 feet in length, 5.5 inches in diameter, upward curved and without enamel, in these respects differing from those of *M. lulli* which, according to Barbour (1934), are downcurved and have some enamel. The teeth are high crowned. The intermediate molars are trilophodont. The two principal upper grinders of the largest individuals have five crests plus a strong cingulum or supplementary crest at the front and a heel or half crest at the rear. The crests are widely separated but strongly supported by cross buttresses placed interior to the median line between the first and second and the second and third crests. In smaller individuals the posterior cone and the cingulum are lacking. The principal lower grinder on large individuals has five crests, cingulum at the front, and one large median conule at the rear. The crests are widely separated but strongly buttressed throughout by conules between the crests placed exterior to the median line. In this way the outer half of the lower tooth is very strongly supported by interconnected cones and

conules. On the very large teeth there is an exterior cingulum more or less strongly developed and beaded with tubercles. The anterior cingulum is either not always present or disappears with wear. The teeth vary considerably. Thus while the largest lower grinders have five crests and a

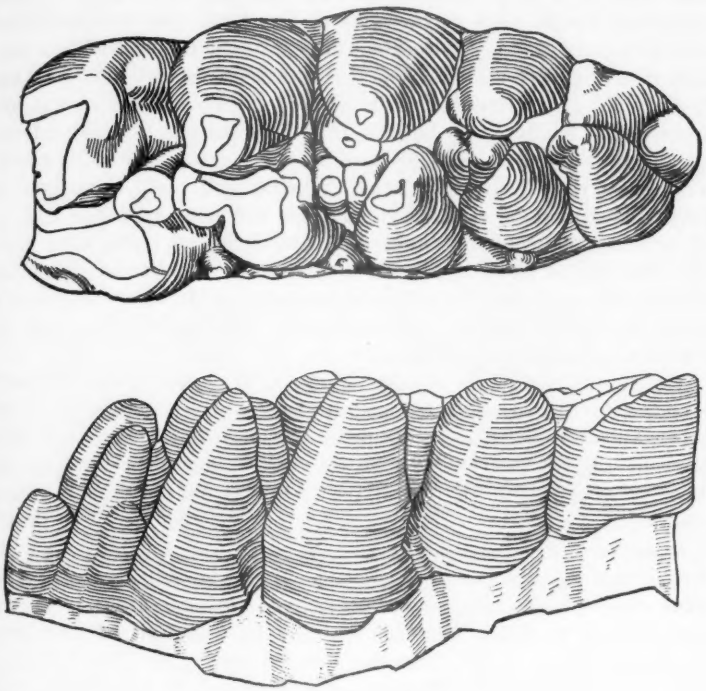

FIGURE 2.—*Left lower large molar*
Crown and side views. No. 274. X½.

posterior cone, some slightly smaller lack the posterior cone; others have four crests and a cone or merely four crests or, as a minimum, three crests and two cones. The teeth of an individual vary. Thus in specimen No. 288 the right large molar, length 7¾ inches, has four crests and an unpaired cone and a rugosity back of the cone. The equivalent tooth on the left side, length 6¼ inches, has four crests, the fourth being reduced and the cone and rugosity absent.

Back of the principal grinder this mastodon has in some individuals an apparently nonfunctional additional tooth in the upper jaw. This

tooth consists of several cones and conules irregularly placed and not forming crests. Of the four skulls now prepared for study, one, an individual in early maturity, has this extra tooth in both jaws; the other, an old individual, has the extra tooth present in the left jaw only. Some depressions in the bone on the right side may represent the almost completely healed scars of the roots of this tooth. Another individual with all molars practically worn out does not have this tooth. It is possible that this tooth emerges from the gum near maturity and drops out in early old age. That the tooth in the left jaw referred to was unopposed by a similar tooth below is proven by the fact that it is unworn by an opposing tooth, notwithstanding that the adjacent large grinder was almost completely worn away. Whether this tooth is vestigial or adventitious may be a question. It does not seem probable that an adventitious tooth would be present in two skulls. It seems more probable that this is vestigial M_3. If so, it follows that the large grinding tooth of this and probably of other mastodons is M_2. This mastodon is large, the overall width of the skull of a large individual across the condyles being about 33 inches.

The generic relation of the new species is in doubt. It is apparently excluded from *Megabelodon* which it resembles in shape of lower jaw because it has long upcurved superior tusks lacking enamel. In 1935 Barbour and Sternberg described the genus *Gnathabelodon* from the Pliocene of Kansas. The tip of the lower jaw of the type species of *Gnathabelodon*, if correctly restored by Barbour and Sternberg (1935), is expanded and is spoon-shaped, and the tusks curved outward, thus differing from the Bee County mastodon. However, until the material at hand can be fully prepared and studied, the new mastodon is referred provisionally to *Gnathabelodon*, the only known genus of long-jawed mastodon with upcurved tusks and tuskless lower jaw. The name proposed for the species is *Gnathabelodon buckneri*, in recognition of the interest and co-operation received from Mr. E. H. Buckner on whose property the fossils were found.

The characters of *Gnathabelodon buckneri* n. sp. are: lower jaws long, downcurved, lacking tusks; tip slightly expanded, bifid, flat on top; intermediate molars trilophodont; principal upper grinders of large individuals have five crests, posterior conules forming a partial crest, and an anterior cingulum; principal lower grinding molar varying, according to size, from five crests, posterior conules and anterior cingulum to a minimum of four crests, the fourth being considerably reduced in some individuals; crests widely separated but well buttressed; crests upon wear developing a three- or four-lobed pattern; superior tusks slender, 5 to 6 feet long, upcurved.

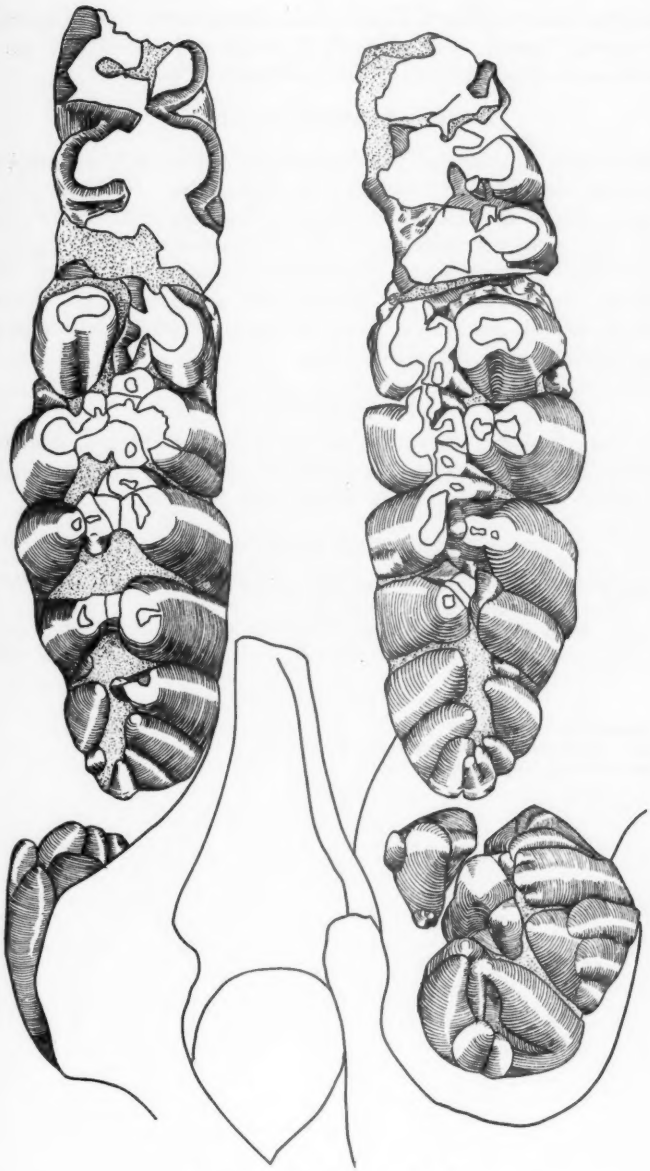

FIGURE 3.—*Palatal view of skull*
No. 389. X⅛.

The type locality is Site 1, Blanco Creek, Bee County, Texas; age middle or upper Pliocene; type material, 15 skulls and associated bones of the skeleton, in the collections of The University of Texas.

OTHER PLIOCENE FOSSILS

The Pliocene collection of vertebrates has not been fully prepared for study, and identification has not been completed. However, W. N. McAnulty who is working on the collection has recognized the following genera and species associated with the new mastodon: *Merychippus* cf. *francisi* Hay, *Nannippus* sp., *Neohipparion occidentale* (Leidy), *Pliohippus* sp., *Teleoceras fossiger* (Cope), *Capromeryx* (?) sp., *Blastromeryx* sp., cervid, genus indet., *Procamelus* sp., *Prosthennops serus* (?) (Cope), canid, genus indet., *Alligator* sp.

CONCLUSION

The fauna from the Goliad formation is definitely Pliocene. However, determination of its place in the Pliocene must await a more complete study of the fauna. It probably is not latest Pliocene.

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FIGURE 1. BIG JOHN BROOK, TOMPKINS, SOUTHERN LONG RANGE PLATEAU
Seen from road on west side of Little Codroy River. Upland surface about head of brook represents Long Range and High Valley peneplains. The 300 to 500 foot threshold of the brook in middleground.

FIGURE 2. CIRQUE AT HEAD OF BROOK EAST OF SADDLE MOUNTAIN
Flat-topped hill in background is part of High Valley Peneplain. Flat-topped hill in right foreground correlates with summit of Saddle Mountain and is about 1200 feet above sea level. Taken from summit of Saddle Mountain.

FIGURE 3. NEAR HEAD OF HIGH VALLEY OF BIG JOHN BROOK
Part of High Valley Peneplain; locality is just above Big John Cirque and about 1750 feet above sea level. Lake on left is the second in succession of three rock basin lakes.

SOUTHERN LONG RANGE PLATEAU

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SURFACE OF NEWFOUNDLAND

BY W. H. TWENHOFEL AND PAUL MAC CLINTOCK

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ABSTRACT

The surface of Newfoundland is complex and owes its character mainly to erosion on complex rock structure, differences in rock resistance, and differential and periodic uplift. Depositional agencies are responsible for some parts of the surface. Striking features are the slight relief of large areas of the upland surface and the rather generally steep slopes to the lowlands. Most steep slopes seem to be fault line scarps. Most lowland areas are on weak rocks.

The highest upland surfaces of slight relief are on the west coast and range in elevation from about 2000 to 2600 feet. This upland surface has been named the Long Range Peneplain. It is represented in the interior of Newfoundland by summits of monadnocks. A second surface of slight relief is represented in the western mountains by high-level valleys in the range of elevation between 1300 and 1700 feet. This is continued eastward over the High Central Plateau of the western part of the interior by a surface of little relief with elevation between 1200 and 1600 feet, and still farther eastward by summits of monadnocks and plateaulike areas in the range of elevation of 1000 to 1200 feet. On the Avalon Peninsula it is represented by upland areas of little relief with elevation of 700 to 800 feet; this has been named the High Valley Peneplain. A third erosion surface on the west coast is represented by dissected upland surfaces from 1000 to about 1100 feet above sea level and by wide mature valleys from 500 to about 1000 feet above sea level.

In the central interior this surface is between 500 and 1000 feet high and it descends to about 200 feet above sea level on the Bay of Exploits. It is about 400 feet high at the Newfoundland Airport and has about the same elevation on the Avalon Peninsula. This has been named the Lawrence Peneplain.

The surface of the parts of Newfoundland studied is described in detail, general summaries of data are made, and interpretations of origin are attempted.

INTRODUCTION

Not much has been written relating to the surface of Newfoundland. A little may be found in the reports of Murray and Howley. The senior writer in 1912 attempted assemblage of published information, supplemented this with data collected on an expedition with Professor Charles Schuchert from the Strait of Belle Isle to Port au Port in the summer of 1910, and included results of observations made by Professor Charles Schuchert on a trip on the railroad from the Bay of Islands to St. Johns. That paper attempted an interpretation of the origin of the surface and postulated a peneplain with elevation around 2000 feet on the west coast. This elevated peneplain was thought to slope eastward and to fall to

around 700 feet at St. Johns on the east coast. However, the quantity of information was limited, and statements of character of the surface and its origin were necessarily tentative. The statement was made that the mountains of the west coast had been glaciated to the summits. This view was later challenged, and the view was stated that the western uplands of Newfoundland had not been glaciated (Fernald, 1930). Coleman stated that the uplands had been glaciated in the Kansan but not in the Wisconsin stage. Expeditions to Newfoundland in 1935 and 1936 convinced the senior author that the physiography of Newfoundland is far more complex than was thought in 1912 and that several erosion levels instead of one are present. It was clear that revision of the views expressed in 1912 was necessary insofar as the physiography was concerned. These expeditions also yielded convincing evidence of very recent and very complete glaciation of each region studied.

The Geological Survey of Newfoundland in recent years has studied different areas of the Island, and evidence of late glaciation was thought to have been found in each. It was thus felt that detailed study of several critical areas was extremely desirable in order to learn the sequence of glacial events; that a general reconnaissance of the glacial geology should be made; and that more extensive and more detailed study of the surface was desirable. A grant from The Geological Society of America financed an expedition made in the summer of 1939. Franz Dykstra, Arnold C. Mason, and W. S. Twenhofel of the University of Wisconsin and William A. Bryan and Stanley E. Harris of Princeton University participated in the study. The Wisconsin students spent the entire field season in Newfoundland, and those from Princeton the month of August. Mason was assigned to work on the Humber River Basin, and Dykstra worked with him. W. S. Twenhofel spent most of the field season on a problem in the Bay of Islands. The Princeton men worked on glacial problems in the St. George Basin. The writers worked together on the southern Long Range Plateau from Port aux Basques to St. Georges, in the regions of Port au Port, Bay of Islands, Bonne Bay, Howley, Red Indian Lake, Buchans, and the Topsails. The senior author walked across the region from Bonne Bay to the Humber River and from Sandy Lake to White Bay. He examined the St. Johns region, and the junior author examined the west end of the south coast. The senior author also studied part of the west side of Notre Dame Bay from Hall Bay to Baie Verte on the peninsula between Notre Dame and White bays. Placentia Bay was visited, the regions around Brigus Junction and Clarenville were studied, and a trip by slow freight train was made from Clarenville to Norris Arm. Several days were spent at Norris Arm, Botwood, Bishops Falls, and Grand Falls.

The Newfoundland Government very graciously permitted the writers to go on one of its routine airplane trips to observe from the air the Long Range Mountains and the Bay of Islands "Serpentine" Range. The flight was made from Spruce Brook in the lowland area east of the Lewis Hills northward along the east side of the Lewis Hills, Blow-me-down Mountains, North Arm Mountain, Table Mountain, Gros Morne, and thence north to Parsons Pond. Return was made on the west side of the same mountains and eastward to the south end of Grand Lake and thence back to Spruce Brook.

Respecting elevations, unless otherwise stated these were taken with barometers which were checked where possible by return to places of starting, to places where elevations had previously been determined, to places of known elevations, or against another barometer on a position of determined elevation. The recorded elevations were then adjusted. On the trip from Clarenville to Norris Arm on the slow freight train elevations were checked against known elevations of stations. Figures are thus fairly but not absolutely accurate. Some elevations were taken from the Geological Map of Newfoundland. These are indicated by the letters G. M. N. in parentheses after the figures. Others were acquired from the Geological Survey of Newfoundland; these are indicated by the letters G. S. N. in parentheses. A considerable number of elevations was received from the Geodetic Service of Canada through courtesy of Mr. W. M. Dennis who is in charge of a co-operative Geodetic Survey of Newfoundland. These are printed in italics.

Work on the physiography of Newfoundland is greatly hampered by lack of topographic maps. The only accurately contoured maps that the authors have seen are those of the Buchans region (Fig. 12), Canada Bay (Betz), Baie Verte-Mings Bight area (Newfoundland Geological Survey, unpublished), and head of White Bay (Newfoundland Geological Survey, unpublished, Fig. 11). Ingerson has published a small scale topographic map of the northern end of the Bay of Islands "Serpentine" Range (Fig. 9).

In addition to the work of Murray and Howley and the paper by the senior author, there have been brief contributions on the physiography of Newfoundland by geologists working in areas where minerals of commercial importance are known, or have been suspected to be present. Reference is made to these contributions in appropriate connections. Among other publications, there is a small map of Newfoundland by Doctor A. K. Snelgrove (in press) on which 12 physiographic divisions of the Island are shown (Fig. 1). Many of the names with the significance given them by Doctor Snelgrove are used on later pages.

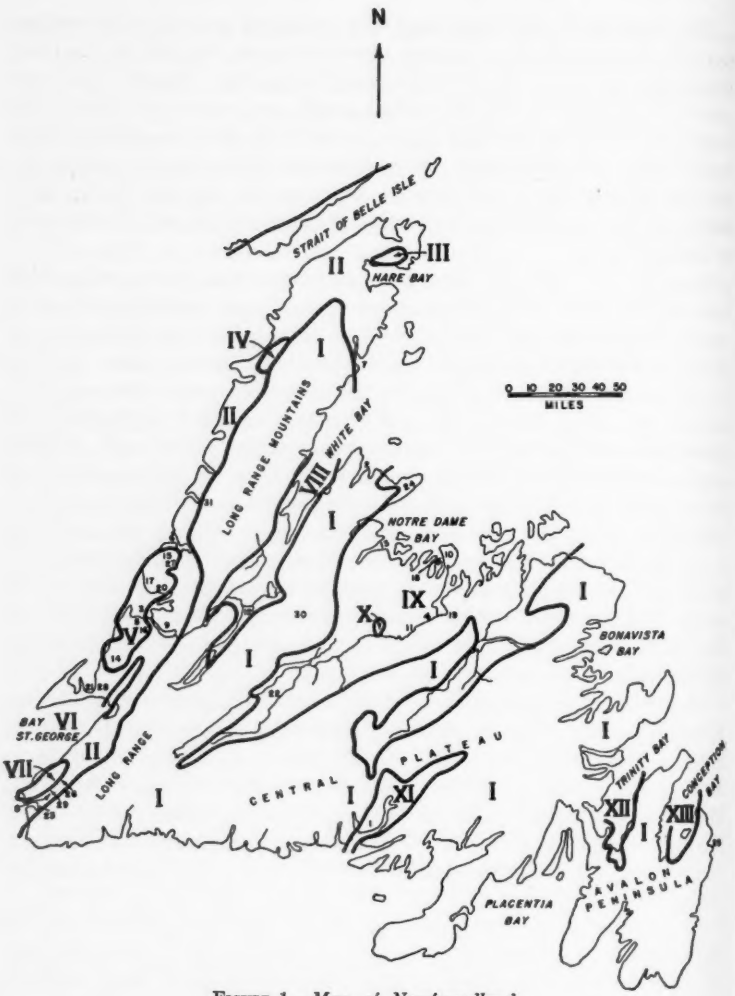

FIGURE 1.—*Map of Newfoundland*

Showing the physiographic divisions of Snelgrove and the localities considered in the text. Physiographic divisions are indicated by Roman and localities by Arabic numerals.

I. Atlantic Upland.
II. West Coast Lowland
III. Hare Bay "Serpentine Hills"
IV. Highlands of St. John
V. Bay of Islands "Serpentine" Range
VI. Indian Head Range
VII. Anguille Mountains
VIII. Grand Lake—White Bay Basin
IX. Notre Dame Bay Basin
X. Hodges Hill Monadnock
XI. Baie d'Espoir Basin
XII. Trinity Bay Basin
XIII. Conception Bay Basin

(Legend continued on page 1671)

The Long Range Mountains and Long Range of this map are the western part of the Atlantic Upland. In the present paper they are together designated the Long Range Plateau with the understanding that the western part of the Atlantic Upland is meant.

In connection with their work in Newfoundland the authors have incurred many obligations. For the funds to make the expedition possible the authors are indebted to the Penrose Bequest of The Geological Society of America. The authors are grateful to the several students who generously paid their own expenses and cheerfully put up with frequently very trying conditions. Dr. A. K. Snelgrove, Director of the Geological Survey of Newfoundland, very generously made available the facilities of the Survey and made it possible for the writers to see the western mountains from the air. The writers accompanied officers of the Geological Survey on boats that made possible examination of part of the west coast of Notre Dame Bay and the west end of the south coast. The people of Newfoundland without exception were extremely hospitable, generous, and willing to aid to the extent of their ability. The authors are greatly indebted to many of them.

Data are presented for separate regions of the Island, beginning in the west. Physiographic sequences of events are suggested. Erosion levels in the western mountains are first described and, then in sequence, those of the Grand Lake-White Bay Basin, the High Central Plateau, and the regions east to the Avalon Peninsula. The map given in Figure 1 should be consulted for localities.

STRATIGRAPHY, STRUCTURE, AND EARLY GEOLOGIC HISTORY

Any attempt to explain the surface of Newfoundland must consider the geologic structure and history of the region, as in these are found many of the factors responsible for features of the Island's surface.

During a considerable part of the Paleozoic and pre-Paleozoic eras, Newfoundland was a part of two basins of deposition of which the southeastern has been designated the Acadian Geosyncline, and the northwestern, the St. Lawrence or northern part of the Appalachian Geosyncline. The two basins were separated by an elevated region which has been termed the New Brunswick Geanticline. The Laurentian shield

1. Baie d'Espoir
2. Baie Verte
3. Bay of Islands
4. Bishops Falls
5. Blow-me-down Mountains
6. Bonne Bay
7. Canada Bay
8. Codroy Basin
9. Deer Lake
10. Fortune Peninsula
11. Grand Falls
12. Grand Lake
13. Hall Bay
14. Lewis Hills
15. Lookout Hills
16. Mt. Musgrave and Steady Brook
17. Mt. St. Gregory Highland
18. New Bay
19. Norris Arm
20. North Arm Mountain
21. Port au Port
22. Red Indian Lake
23. St. Andrews
24. St. John Peninsula
25. St. Johns
26. South Branch
27. Table Mountain, Bonne Bay
28. Table Mountain, Port au Port
29. Tompkins
30. Topsail Region
31. Western Brook Pond

lay northwest of the St. Lawrence Geosyncline, and it has been assumed that an ancient land, designated Nova Scotica, margined the Acadian Geosyncline on the southeast. Sediments deposited in these two geosynclines became the pre-Cambrian and Paleozoic sedimentary rocks.

The Avalon Peninsula and the eastern margin of the main part of Newfoundland were a part of the Acadian Geosyncline, and all of Newfoundland west of the eastern side of Notre Dame Bay and nearly to the eastern side of the Gander River Basin were in the St. Lawrence Geosyncline. Present boundaries of the strata deposited in the two geosynclines leave little space for the New Brunswick Geanticline. The space may have been much greater before Newfoundland was shortened by diastrophism. The geanticline and the two geosynclines had northeast-southwest trend.

The Acadian Geosyncline was folded some time after the early Ordovician, the time generally considered to have been in the late Devonian. The St. Lawrence Geosyncline is thought to have been somewhat deformed during the closing Ordovician, again during the late Silurian, perhaps in the late Devonian, and lastly during the late Pennsylvanian or Permian. The diastrophism was expressed in both geosynclines in intrusions, extrusions, folding and faulting. Many folds are overturned with axial planes dipping to the southeast, and most faults have the same inclination. Most faults are thrusts to the northwest, and distances of movement in some cases are thought to be measured in miles. Several that have been described are the thrust in the Lewis Hills, the thrust on the west side of the Long Range Mountains, the thrust on the east side of the Codroy Valley and St. George Basin, the Grand Lake-White Bay thrust, and in the Notre Dame Bay region the Luke Arm thrust described by Heyl. Others are known.

The folds and faults have northeast-southwest trend and their development placed zones of weakness on the surface with northeast-southwest orientation. Erosion took advantage of this situation with the result that zones of strength formed ridges and zones of weakness depressions. Streams occupied the depressions and, under conditions of complete adjustment to structure, flowed to the northeast or to the southwest. Submergence drowned lower parts of valleys, thus forming bays and peninsulas with orientation of the valleys and ridges. These, in general, are the present conditions.

Prior to the Ice Age there was a long period extending as far back as the late Pennsylvanian during which Newfoundland was subject to some degree of erosion. It is probable that during this long interval the land was repeatedly elevated and depressed. Each uplift led to erosion along weak zones and intensification of relief, and each period

of stability reduced heights of ridges and formed surfaces that more or less gently sloped from sources of streams to mouths, thus making partial or complete peneplains. It is probable that, during later stages of periods of stability, the central area of Newfoundland was the source of most of the streams which flowed to the sea in accordance with slope or structure. Among the streams of the later part of the long erosional history before the Ice Age were the precursors of the Codroy, Humber, Exploits, Gander, and others. These streams tended to become adjusted to structure—the Codroy in the weak Pennsylvanian strata in the southwestern part of the Island, the Humber and its tributaries in the Grand Lake-White Bay zone of weakness, and the Exploits and its tributaries in the weak Paleozoic strata where the river now flows. The streams always tended to flow northeast or southwest rather than across structure until planation had eliminated structural control when they might acquire courses transverse to structure. The Humber, Lomond, and several other streams of the west coast are assumed to have acquired present courses under conditions of little elevation and relief.

The present surface of Newfoundland seems to indicate that the latest regional uplift was greater on the west coast than on the east, thus tilting the original surface to the southeast. This must have encouraged capture of headwaters of west-flowing streams by streams flowing either parallel to structure or in the direction of tilting. The Humber, Lomond, Serpentine, and a few other streams seem to have been able to hold courses both transverse to structure and opposite to direction of tilting and thus now reach the sea across the region of greatest uplift. It may be that such persistence across the region of greatest uplift was aided by presence of transverse zones of structural weakness. This is the case for Serpentine Brook which rises on the east side of the Bay of Islands "Serpentine" Range and flows entirely through this range to reach the Gulf of St. Lawrence. The Humber and Lomond rise in the Grand Lake-White Bay Basin on the east side of the present Long Range Plateau and flow entirely through that upland and also the Bay of Islands "Serpentine" Range to reach the Gulf of St. Lawrence. Lomond Valley has a mature cross profile and low gradient from the head of East Arm of Bonne Bay to the sources in the Grand Lake-White Basin, but a youthful profile from the head of East Arm to the Gulf of St. Lawrence. The valley of the Humber has a mature cross profile, except for the last 3 to 4 miles above the Bay of Islands where it is youthful. Hughes Brook, north of the Humber River and flowing into Wild Cove of Humber Arm, has a mature valley profile, and this may have been the pre-Wisconsin valley of the Humber River. Streams like St. Georges River and Corner Brook, which now rise on the Long Range Plateau on the

very edge of the escarpment of the Grand Lake-White Bay Basin, may have had headwaters farther east than now and may have headed on rocks which once filled this basin to the same level as the surrounding region. These headwaters may have been captured by streams on the weak rock of what has now become a lowland.

The logical direction for drainage in the Grand Lake-White Bay Basin is into White Bay. It is not unlikely that this may have been the case one or more times during the long Pennsylvanian-Pleistocene interval, but during some late period of stability it is assumed that the precursors of the Humber, Lomond, and other west-flowing streams acquired courses across the regions where now rise the Long Range Plateau and the Bay of Islands "Serpentine" Range. They retained these courses as the mountains rose. They are thus considered streams superimposed from a peneplain and also in a sense antecedent in that they flow against the regional slope produced by later uplift.

During the Ice Age Newfoundland was completely glaciated. The ice cover was thick. Present evidence indicates that the known ice cover belonged to the Wisconsin stage. Earlier glaciers may have been present, but, if they were, the traces were removed by Wisconsin ice. During the maximum intensity of Wisconsin glaciation Newfoundland supported a thick ice cap from which ice radiated in all directions. The valleys of the Codroy, St. Georges, Harrys, Serpentine, Humber, Lomond, Victoria, Gander, Exploits, and other rivers were channels leading glaciers outward from the High Central Plateau and other parts of the Atlantic Upland. Waning of glaciation led to local ice caps and valley glaciers, the former removing foreign erratics from uplands, and the latter building such wonderful moraines as may be seen on Kittys Brook and other brooks flowing from the upland into Humber Valley, between Sandy Lake and White Bay, about Red Indian Lake, and many other places.

Glacial erosion and deposition disorganized previous drainage, excavated numerous basins, and dammed valleys. Disappearance of the glaciers—which is not yet complete as snow and ice remain in shaded valleys throughout the summer—was followed by very little modification of the glacial topography. There has been little post-glacial erosion.

Channels of glacial passage to the sea were deepened, in many cases below sea level, and sides of channels were steepened. Submergence followed glaciation, and ice-eroded channels were carried deeper beneath the waters of the sea. These channels became fiords, branching in some cases, like the Bay of Islands and Bonne Bay, and in others single, like many on the north coast. Since submergence there has been uplift,

greatest in the north, where raised marine terraces are obvious, and least in the south.

Thus the present surface of Newfoundland owes its origin to the impact of fluvial and glacial erosion on various kinds of structure during differential and periodic vertical movement. Periods of stability produced more or less perfect peneplains. Glaciation gave some detail. Submergence indented the coast with bays and dotted the marginal waters with islands.

SOUTHERN LONG RANGE PLATEAU

INTRODUCTION

The Plateau of the southern Long Range was studied at Tompkins (Fig. 1), South Branch, and St. George Basin; it rises abruptly from the lowland at all these places and is composed of igneous and metamorphic rocks which consist of granite, granite pegmatite, various basic and ultrabasic crystallines, gneiss, and schist. Schistosity and gneissosity do not seem to have any significant relation to the character of the surface. They are cut in many places by veins of milky quartz, some of which are 10 feet wide. The rocks have been assigned to the pre-Cambrian, but all that is really known is that they are older than the Mississippian. Some of the metamorphic rocks are of sedimentary origin. It is probable that some of the intrusives are of Paleozoic age.

Slopes from lowland to upland are generally steep (Pl. 1, fig. 1; Pl. 2, fig. 1). Timber is usually present to the top of a slope but is dwarfed adjacent to the top.

Mountain glaciation is indicated by U-shaped valleys, hanging valleys, cirques, and tarns. Streams on the Plateau flow in broad open valleys (Pl. 1, fig. 3; Pl. 2, fig. 2), cascade from the plateau surface into cirques (Pl. 1, fig. 2), flow with more or less steady waters to thresholds of canyons where from levels of 300 to 500 feet they descend rapidly to the adjacent lowland (Pl. 1, fig. 1; Pl. 2, fig. 1). The plateau part of a stream for a short distance before plunging into a cirque may flow in a V-incision within a broad open valley.

The steep slope from the lowland to the upland is a fault line scarp of a reverse fault which thrust the igneous and metamorphic rocks of the Long Range Plateau westward over the Paleozoic which now forms the surface strata of the Codroy, St. Georges, and intervening lowland. This fault was long ago pointed out by Murray and Howley (1881), was noted by Mook (1926) at South Branch, and has lately been described by Hayes and Johnson (1938). It is easily seen in the canyons that indent the escarpment as Paleozoic strata are overlain by the igneous and metamorphic rocks composing the plateau.

Most canyons in the Long Range Plateau south of South Branch are less than a mile long. That of Big John Brook, one of the largest, is 1 to 2 miles long. The canyons of some of the streams north of South Branch are much longer. Those of the Little Codroy, Codroy, Flat Bay,

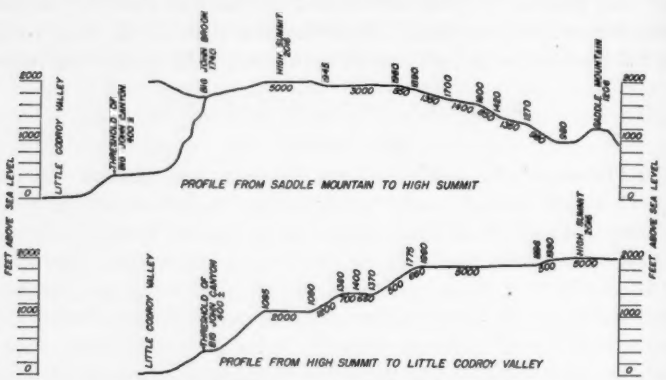
FEET ABOVE SEA LEVEL
LITTLE CODROY VALLEY
THRESHOLD OF BIG JOHN CANYON 400 ±
BIG JOHN BROOK 1240
HIGH SUMMIT 2048
SADDLE MOUNTAIN 2048
PROFILE FROM SADDLE MOUNTAIN TO HIGH SUMMIT
PROFILE FROM HIGH SUMMIT TO LITTLE CODROY VALLEY

FIGURE 2.—*Profiles in southern Long Range Plateau*

From Saddle Mountain to High Summit and from High Summit to Little Codroy Valley at the end of the long spur between Big John and Doucets brooks. All distances are in feet.

and some others extend into the Plateau for several miles, that of St. Georges River a dozen or more miles.

Snow lies in shaded areas of the southern Long Range Plateau for much of the summer, and patches several acres in area were abundant in early July 1939. The snow is responsible for much meltwater erosion of the surface beneath as this is without vegetable protection.

LONG RANGE PLATEAU AT TOMPKINS

Tompkins (Fig. 1) is 22 miles north of Port aux Basques, the southwestern terminus of the Newfoundland Railway, and 16 miles north of Cape Ray. The upland at this place was studied from Saddle Mountain, a little south of Tompkins, northward to beyond the canyon of Big John Brook, a distance of about 5 miles, and eastward for half a dozen miles. An area of perhaps 30 square miles was seen. Ascent was made over the same trail by which Coleman climbed to the Plateau. Coleman spent a part of one day on the Plateau, the senior author spent 4 days.

The profiles of Figure 2 show the nature of the upland surface and give the elevations. The elevations were determined with barometer, readings being controlled by placing a man on the triangulation station on Saddle Mountain (*1206* feet) with instructions to record the barom-

eter reading every 10 minutes. One profile of Figure 2 extends from the summit of Saddle Mountain to the top of the high summit just south of the head of Big John Brook. The field barometer was read at each change of slope. Distances were determined by pacing. The second profile of Figure 2 extends from the high summit just south of the head of Big John Brook to the end of the long spur between Big John and Doucets brooks.

The profiles show that there is a gently sloping surface (1) in the range of elevation from 1000 to 1100 feet, (2) in the range from 1290 to 1420 feet, (3) in the range from 1600 to 1700 feet (Pl. 1, fig. 3; Pl. 2, fig. 2), (4) on the highest part of the Plateau where there is a remarkable subdued surface in the range of elevation from 1850 to 2016 feet (Pl. 2, fig. 3). Parts of the last named are essentially flat.

Saddle Mountain (1206 feet) has a very flat summit, steep sides, and the underlying rock has a complex structure. It is least steep on the side toward the Saddle where connection is made with the Plateau. Sides are very steep to the south and southeast where there is an oversteepened valley heading in a cirque. Slopes of intermediate steepness are present on the southwest and west. The level of Saddle Mountain is thought to be present on the other side of the Saddle in the low slope area from 1290 to 1420 feet. This level is also represented on the flat area from 1380 to 1400 feet on the profile from the summit to the end of the spur between Big John and Doucets brooks. This is lower in the rear than on the end because small tributaries of Big John and Doucets brooks head there. More or less gently sloping areas of these elevations are present on adjacent parts of the upland.

The Saddle is a nearly flat area which is 980 feet high on its lowest part. Another flat area of about the same elevation is shown on the summit of the long spur (1080–1095 feet) between Big John and Doucets brooks. Other areas with about the same range of elevation are present on other spurs of the Plateau.

The level from 1600 to 1700 feet is very marked on the profile from Saddle Mountain to the high summit but it is barely apparent on the profile from the summit to the end of the long spur between Big John and Doucets brooks. It is present on other parts of the upland and is thought to be excellently shown in the upland valleys of Big John and other brooks (Pl. 1, fig. 3; Pl. 2, fig. 2).

The most impressive level is that of the high summit with elevation from 1850 to 2016 feet (Pl. 2, fig. 3). This has an area of about one square mile and, if one were placed in the center of this level area where he could not see the margining lower lands and was not aware that such

lower lands existed, his impression would be that of being on an almost level plain.

The profiles indicate the steepness of slopes from level to level. Ascents from the Saddle (about 1000 feet) to the 1290–1420-foot level and from the latter level to the 1600–1700-foot level are very steep. On the second profile the slope from the 1080 to 1090-foot level to the 1380 to 1400-foot level is extremely steep. The rise to the high summit is gentle.

The surfaces of levels [1] and slopes are mostly moss- or grass-covered, but growths of waist to breast high balsam, spruce, and alder are present on protected areas. These patches were formerly more extensive but have been reduced by fire. There are occasional patches of broken rock of which many are rounded. The pieces on lower levels have maximum dimension of 1 to 2 feet, but there are blocks on the summit level up to 10 feet long. Rocks of lower levels are varied in composition, those on the highest level were largely derived from the underlying terranes, but there are some that are foreign to the region and could not have attained present positions except by glacial transportation. Some of the broken blocks may be remains of large erratics; others have the outlines of roches moutonnées. The breaking of the rocks is due to frost action which is of great intensity in Newfoundland.

The lower valley of Big John Brook is a canyon about a mile long which terminates in a cirque. In contrast, the valley on the upland above the cirque is wide, flat-floored, and has gently sloping sides. The upland valley contains a succession of lakes of which three lie in rock-bound basins just above where the stream cascades into its cirque and canyon (Pl. 1, fig. 3). The surface of the lowest lake is about 1730 feet above sea level; the floor of the cirque is about 1000 feet lower. The elevation of the head of the upland valley at the divide is estimated to be a little under 1800 feet. Other valleys on and indenting the Plateau exhibit similar features.

Excellently preserved roches moutonnées are present on the floor and sides of the Big John upland valley and are splendidly shown adjacent to the outlet of the lowest lake. Large and small erratics are numerous. Some are as high as a man, and both native and foreign rocks are represented. A large glacier once filled this upland valley, and its extensions are thought to have at one time completely covered the highest parts of the upland.

The surface of this more or less grass- and moss-covered upland valley bears a striking resemblance to the broad valleys of the western plains of the United States, the only apparent difference being absence in the

[1] The flat upland areas of the mountains are termed "levels" by the people of western Newfoundland.

FIGURE 1. LONG RANGE PLATEAU FROM ST. ANDREWS
Shows flat-topped upland and 300- to 500-foot level at thresholds of brooks.

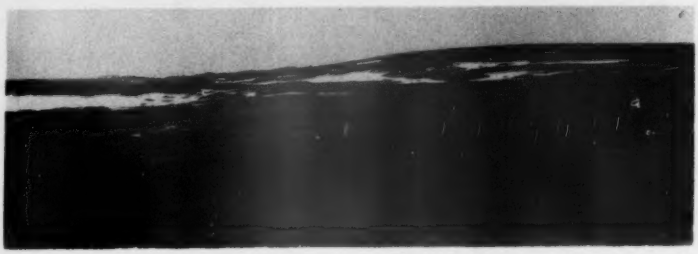

FIGURE 2. LONG RANGE PLATEAU—THE HIGH VALLEY PENEPLAIN
Near top of divide at head of Big John Brook.

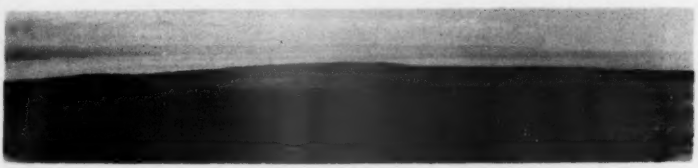

FIGURE 3. SUMMIT OF LONG RANGE PLATEAU
South of the head of Big John Brook, the 2000-foot level. Remnant of the Long Range Peneplain.

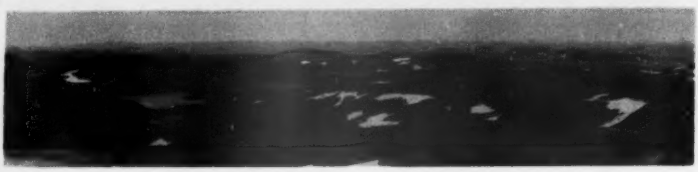

FIGURE 4. LONG RANGE PLATEAU AT SOUTH BRANCH
Glaciated, lake-dotted rolling surface represents the High Valley Peneplain.

SOUTHERN LONG RANGE PLATEAU

FIGURE 1. TABLE MOUNTAIN AT BONNE BAY
The 2000-foot level of the Long Range Peneplain. Photograph by Charles Schuchert.

FIGURE 2. EASTERN ESCARPMENT OF BLOW-ME-DOWN MOUNTAINS
Summit of mountains is remnant of High Valley Peneplain.

FIGURE 3. SURFACE OF TABLE MOUNTAIN, PORT AU PORT
Surface is considered western extension of Lawrence Peneplain. Boulder is large granite erratic with fresh surface. Underlying rock is limestone. Erratic is 1140 feet above sea level.

LONG RANGE, HIGH VALLEY, AND LAWRENCE PENEPLAINS

Newfoundland valley of cliffs and steep slopes arising from unequal resistance to erosion of horizontal strata. No apparent differential deepening of the valley was done by glacial erosion, thus supporting the view that the ice was thick and completely covered the upland. There seems to

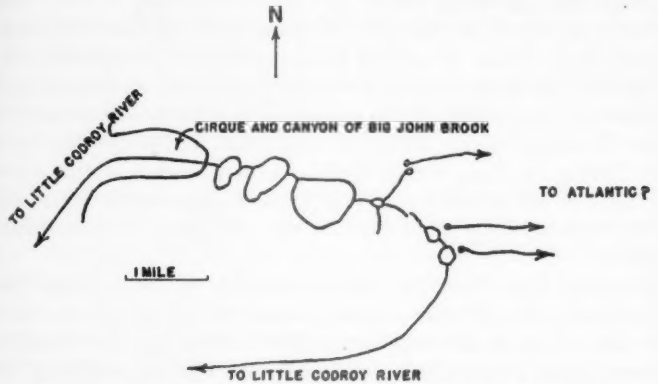

FIGURE 3.—*Field sketch of high valleys at head of Big John Brook*
Directions of streams are approximate. Near Tompkins, south end of the Long Range Plateau.

have been little or no oversteepening of the sides and no sharpening of slopes as would have been the case had glaciers for long occupied only the valley and not have covered the margining higher areas. Marks of glaciation in the form of erratics and roches moutonnées are most distinct up to the elevation of about 1900 feet.

The head of the valley of Big John Brook lies in a gently undulating upland area from which four other streams flow—one southward to reach the Codroy Basin south of Saddle Mountain, the other three southeastward toward the Atlantic. The three valleys that trend southeastward have their heads separated from the other two by a very low col, and one heads with a tributary of Big John Brook in two lakes that lie on the same level and are separated by only about a score of feet. The valley of Big John Brook and that of the stream flowing east of Saddle Mountain are not separated by a col but begin on the same nearly flat surface between the higher margining areas. The diagram of Figure 3 is a field sketch of the five upland valleys. Many lakes are omitted. Lakes in the upland valley of Big John Brook are shown on Figure 3 of Plate 1.

The upland area drained by the five valleys was once the site of a large snowfield that fed ice to Big John Brook, to the valley south and

east of Saddle Mountain, and to the other valleys flowing to the Atlantic.

It is quite obvious that the upland valleys could not have developed under present conditions. They must have been formed in a preceding cycle when the present surface of the Long Range Plateau at this place was very little above sea level.

The steep slope from the Little Codroy Valley to the summit of the Plateau has a terrace or decided break in the slope at elevations of 300 to 500 feet. No measurements were taken; estimates were made by comparison with the summit of the escarpment. This terrace is best shown in the thresholds of the brooks. It was noted by Murray that streams after leaving the Long Range Plateau have stretches of still water at elevations of 400 to 500 feet. This break in slope seemingly is related to the Carboniferous strata beneath the overthrust block forming the Plateau.

There thus seem to be four upland levels on the Long Range Plateau at Tompkins: (1) the summit level from about 1850 to a little over 2000 feet; (2) a level in the range from 1600 to 1700 feet and thought also to be expressed in the wide upland valleys of Big John and other brooks (the heads of these seem to lie at about 1800 feet); (3) the level of the summit of Saddle Mountain and terraces on higher elevations (1290-1420 feet); and (4) the level of the Saddle (1000-1100 feet).

The physiographic development of the Long Range Plateau at Tompkins seems to have been about as follows:

(1) Complete peneplanation of the region of the present Long Range Plateau. This developed a surface of very moderate relief of which an extensive remnant remains on the high summit (1850-2016 feet).

(2) Elevation that raised the peneplain at least 400 feet followed by stillstand to produce the wide mature valleys of Big John and other brooks. These valleys are thought to have developed as the 1600 to 1700-foot level was formed.

(3) Additional elevation to permit formation of the erosional surface indicated by the 1290 to 1420-foot level.

(4) Further elevation to form the 1000 to 1100-foot level shown on the Saddle and numerous spurs between the brooks.

(5) Elevation to something like present position followed by erosion of the Codroy Valley and canyon notches in the escarpment.

(6) Glaciation which at the maximum covered the entire region but was limited during the last phase to the peripheral valleys of the Plateau which were oversteepened and had cirques developed at their heads.

(7) Deglaciation which was so recent that very little erosion has been done.

LONG RANGE PLATEAU AT SOUTH BRANCH

South Branch (Fig. 1) is about 12 miles north of Tompkins and about 25 miles from Port aux Basques. The slope from the lowland to the summit of the plateau is like that at Tompkins. The summit has few extensive flat areas, and the entire surface is dissected to late maturity on which streams flow in aimless courses between the many lakes and ponds. Swamps are abundant.

Erratics and roches moutonnées are numerous on the upland surface, and the rounded outlines produced by glacial erosion are conspicuous. The surface was clearly entirely covered with ice during the Wisconsin stage.

The high valleys, which evidently correspond to the high upland valleys on the Long Range Plateau at Tompkins, have mature topography. They more or less merge at their heads or are separated by low cols (Pl. 2, fig. 4). Streams cascade from the high valley levels into cirques that head the canyon notches indenting the Plateau. An interesting feature of some valleys is that some tributaries rise near the very edge of the escarpment and flow eastward. This is shown in Figure 4 (a field sketch). This may indicate that these valleys originated when the surfaces of the Plateau and the Codroy Lowland had not yet been differentiated into upland and lowland. The elevations of the bottoms of the upland valleys where streams cascade from the Plateau are about 1540 feet, and they head at about 1700 feet.

LONG RANGE PLATEAU AT ST. GEORGES BASIN

The Plateau (Fig. 1) was studied near Steel Mountain (*1005* feet) and south of Flat Bay Brook near Mt. Howley (1529 feet, G. M. N.). The region studied is known locally as the Three Brooks Hills. The steep ascent from the lowland is a fault line scarp as in the Codroy Valley, and the thrust may be seen in Steel Mountain. The summit of the Plateau is somewhat different from that at Tompkins and South Branch. Glacial phenomena are equally if not more apparent, but dissection of the upland surface has been deeper. Tops of elevations are gently rounded, fairly broad, and have a maximum local relief for small areas of the upland surface of 25 to 50 feet and, if broad areas are considered, perhaps 100 feet. The upland surface is around 1500 feet above sea level, and ascent to this level is steep. This upland surface is thought to correspond to the high valleys at Tompkins and South Branch, and it is assumed that nothing remains of the high summit level. Valleys in the upland surface have cirques at their heads that are 100 to 200 feet below the upland, and below these valleys steep slopes drop into broad valleys of mature

aspect. Their floors are about 1000 to 1100 feet above sea level; it is suggested that this level corresponds to the 1000 to 1100-foot level on the Long Range Plateau at Tompkins. These are cut below the upland

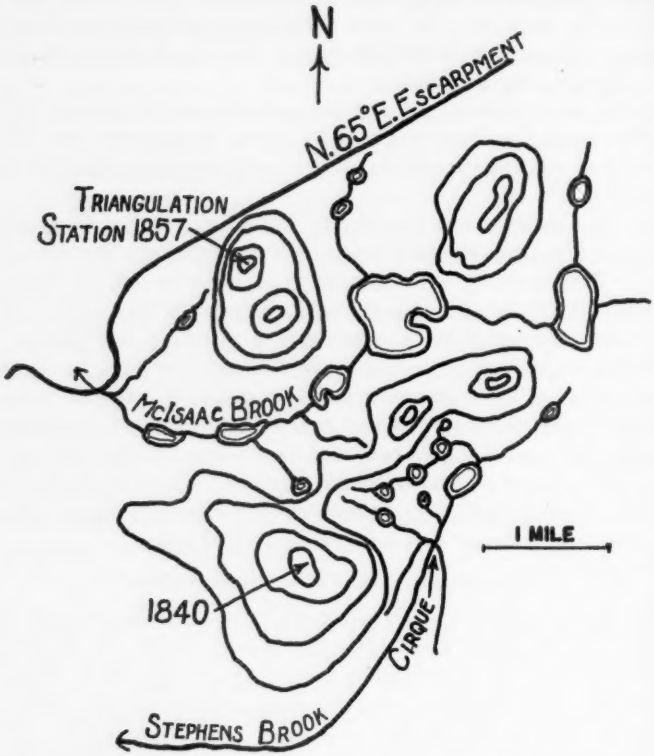

FIGURE 4.—*Surface features on the Long Range Plateau*

About the upland valley of McIsaac Brook. Field sketch. The bend in the escarpment where crossed by McIsaac Brook is the beginning of a drop of around 1000 feet. Stephens Brook continues to the southwest and west ultimately to make a similar drop of around 1000 feet.

surface to depths estimated to range from 400 to 500 feet. They have oversteepened sides, particularly where narrow, and this oversteepening is responsible for the hanging tributaries with cirques at their heads. A field sketch is shown in Figure 5. The high valleys around 1000 feet contain many lakes and lakes are commonly present on the cirque level of the tributaries.

The physiographic development seems to have been about as follows:

(1) Development of a mature upland surface at what is now about 1500 feet.

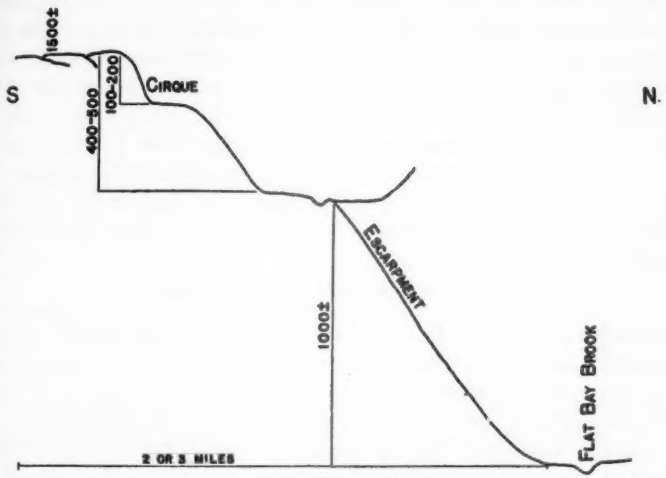

FIGURE 5.—*Profile from floor of Flat Bay Brook Valley to summit of upland at St. Georges Basin*

The flat-floored valleys at around 1000 feet are shown with hanging tributaries from cirques of which the floors are 100 to 200 feet below the upland surface.

(2) Uplift of 400 to 500 feet and development of the present high valleys.

(3) Uplift leading to the development of the canyon notches into which the streams now cascade.

(4) Complete glaciation which dwindled to valley glaciers in the upland valleys and formed cirques at the heads of tributaries. The large valleys are thought to have undergone considerable deepening at this time.

Possible remnants of high summit levels corresponding to that of the Plateau at Tompkins may be present on Hare Mountain (*1958* feet), about 17 miles northeast of St. Georges, and on the Indian Head Range on the north side of Bay St. George (2290 feet, G. M. N.). Neither of these mountains was studied.

ANGUILLE MOUNTAINS

Hayes and Johnson (1938) describe the Anguille Mountains (Fig. 1) as "an upland surface with a flat-topped summit 1800 feet above sea

level." The mountains are composed of steeply dipping Paleozoic sediments. Through the courtesy of Mr. W. M. Dennis of the Geodetic Service of Canada, elevations of triangulation stations in the Anguille Mountains were acquired. From south to north these are *978, 1026, 1198, 1482,* and *1795* feet. Extents of areas corresponding to these elevations are not known. Seen from the summit of the Long Range Plateau it is judged that much of the north end of the summit lies at about the 1800-foot level. The first three elevations fall in line with the 1000 to 1100-foot level of the Long Range Plateau. The other two may correspond to the high valley level, but as the mountains are composed of weaker rock than the Plateau and as they are close to the sea it is possible that the most northern corresponds to the level of the high summit.

TABLE MOUNTAIN, PORT AU PORT

Table Mountain (Fig. 1) is composed of more or less steeply inclined Ordovician limestones. Weak members, where exposed, have broken down into rubble through frost action; strong members remain as more or less shattered to very well-preserved roches moutonnées with elongation parallel to strike. The mountain is a north-south ridge which is highest in the middle where the elevation is *1185* feet. The summit on the south end is 940 feet high (barometric). The north end is estimated to be about the same height as the south. A rock basin containing water is at an elevation of 1160 feet on the north end of the high summit, and there is a considerable lake on the south end at an elevation of 940 feet. Both basins are due to glacial erosion. The summit has a flat to gently sloping surface and it is particularly flat on the highest part (Pl. 3, fig. 3). A brook on the west slope of the south end of the mountain has cut deeply into the summit. The brook has a mature valley of pre-Wisconsin origin, but a V-incision in its floor from 30 to 40 feet in depth has been formed since the disappearance of the ice.

A diagram of the summit is shown in Figure 6. This shows two levels, that of the north and south ends at about 940 feet and the high [illegible] at *1185* feet. The slope to the south from the highest part of the [illegible] is gentle, but it is rather abrupt to the north. This upland surface may possibly represent two stillstands of the region, the first when the high summit was cut and sea level stood some 1100 feet higher than now, and the other when it fell some 200 feet lower. It does not seem necessary to make these assumptions, however, as the entire upland surface may have been eroded at any one position of sea level since all surfaces eroded by streams must have some differences of elevation. After forma-

tion of the present upland surface sea level fell, and there may have been several stillstands. Glaciers completely covered the mountain as proven by numerous fresh erratics and well-preserved roches moutonnées on the highest parts of the summit. The glaciers produced some erosion, and the steep slopes on the west side of Table Mountain may be due to them.

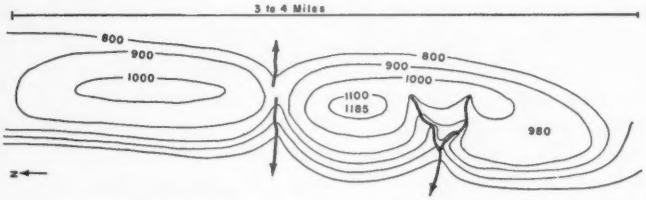

FIGURE 6.—*Field sketch of the summit of Table Mountain, Port au Port*
The gently sloping upland surface should be noted. The underlying rocks are steeply inclined Ordovician limestones.

It is suggested that the summit of Table Mountain corresponds to the 1000 to 1100-foot level of the southern Long Range Plateau.

BAY OF ISLANDS "SERPENTINE" RANGE

GENERAL STATEMENT

The Bay of Islands "Serpentine" Range (Figs. 1, 7) includes the Lewis Hills and Blow-me-down Mountains south of the Bay of Islands, North Arm Mountain on the north side of that bay, the St. Gregory Highland on the north entrance of the bay, Table Mountain on the south side of Bonne Bay, and Lookout Hills on the south entrance of Bonne Bay. All of these mountains seem to be parts of an intrusive complex which has been broken up by faulting. Each is described in such detail as available information permits, or as is necessary for the present objective.

LEWIS HILLS

Lewis Hills were carved from a great block of basic and ultrabasic in[illegible]es thrust from east to west over Ordovician sediments into which they were originally intruded. According to Cooper, this is best interpreted as having taken place on a single low-angle thrust plane. The movement involved a thrust of nearly 6 miles and placed the crystalline rocks of the Lewis Hills over relatively weak Ordovician clastics. The relation of the stronger crystallines over relatively weak clastics is ideal for the development and persistence of a steep scarp such as exists on the west side of the Lewis Hills. The fault relations are shown in

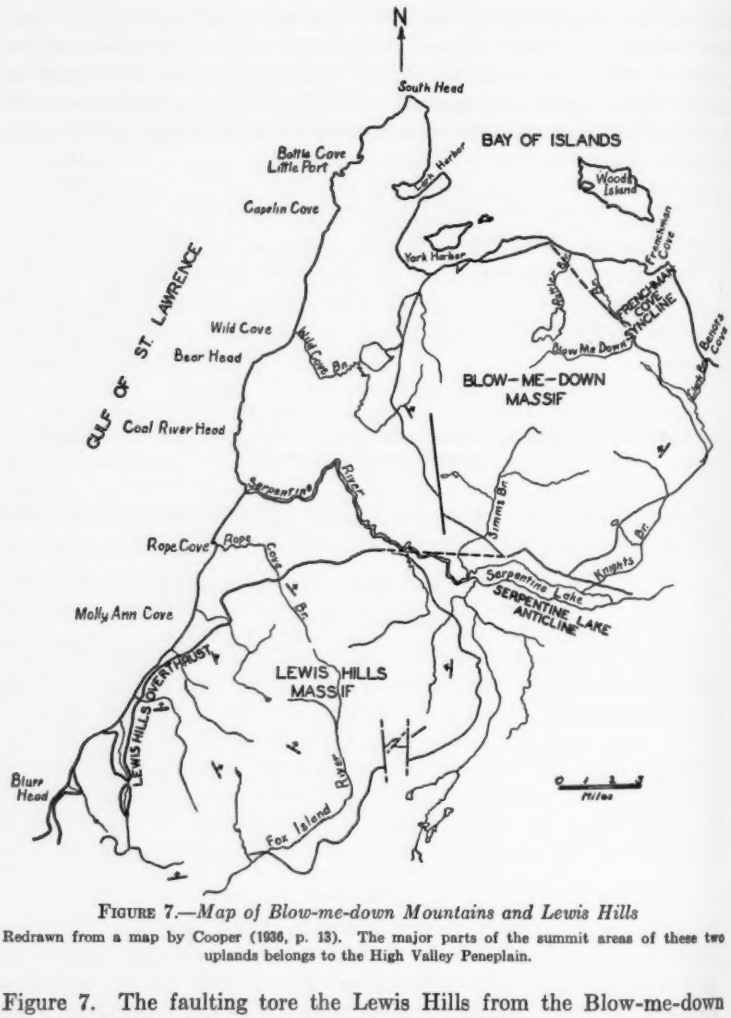

FIGURE 7.—*Map of Blow-me-down Mountains and Lewis Hills*

Redrawn from a map by Cooper (1936, p. 13). The major parts of the summit areas of these two uplands belongs to the High Valley Peneplain.

Figure 7. The faulting tore the Lewis Hills from the Blow-me-down Mountains with which the rocks of the Lewis Hills were once connected. A lowland area, now occupied by Serpentine Lake and Serpentine River developed along the line of faulting between the two mountain areas.

Cooper (1936, p. 3) states that

"there can be no question of the existence of a peneplain in the region here studied, for a rolling stream-cut upland of remarkable integrity forms the summit of the

Bay of Islands Range. The relief of this upland surface is more than 500 feet, which is greater than is generally supposed to exist on the adjacent Long Range Mountains of Western Newfoundland. . . .

"A remarkable flat-topped upland of the Lewis Hills suggests that the summit of the Bay of Islands Range may record two cycles of erosion, and older, more perfect peneplain occurring above the one just mentioned. This mountain, which is known locally as the Big Level, has a nearly flat summit, half a mile in diameter, and stands sharply above the surrounding upland."

The stream in a wide valley on the south side of the Lewis Hills is 830 feet above sea level near Rabbit Mountain. This is thought to be representative of some other streams in the region. A tributary of this stream drains an area that is also drained by the head of Lewis Brook. The floor of the valley rises gently from its lowest part for about three-fourths of a mile to the foot (1100 feet) of Rabbit Mountain (1480 feet). The slope to the summit of the mountain is very steep. The stream in the valley is narrow, not deep, and the dimensions are altogether disproportionate to the width of the valley. The valley owes its great width, gently sloping floor, and steep sides to glacial erosion. It is suggested that this and similar valleys in the Lewis Hills correspond to the summit level of Table Mountain, Port au Port, and were carved during the same stillstand that produced the more or less flat summit of that mountain.

The summit of Rabbit Mountain is a part of a more or less gently rolling surface which ranges in elevation from about 1350 to over 1730 feet. This level, termed the 1300 to 1700-foot level, extends more or less completely around the high uplands of the Lewis Hills and includes the rolling stream-cut upland in which the steep-sided 500-foot canyon of Lewis Brook is cut. An area of about 10 square miles between Lewis Canyon and the bold headland of Bluff Head on the Gulf of St. Lawrence belongs to this level. This area is remarkably flat and little incised by streams, and the surface is dotted with numerous lakes, ponds, and swamps. Gently rounded hills border it on the south. The surface has an impressive appearance of very late maturity.

There is a sloping upland area at about 1830 feet (barometric) on its lower edge. This area is fragmentary but it may be seen above Rabbit Mountain below the Big Level or the summit area of the southern Lewis Hills. It may be a part of that level but it seems more likely to be the result of a different geomorphic episode. The rise to the Big Level from the 1830-foot level is steep and essentially uniform to the present edge of the 2330-foot (barometric) level. The highest point on the Big Level (triangulation station) is *2458* feet. The rise of 128 feet from its edge (2330 feet) is made in a distance of 1500 feet at the place where the ascent was made. The summit of the Big Level is a remnant of a remarkably flat old age erosion surface. Another remnant is

present on Mt. Barren (2311 feet G. M. N.) on the north end of the Lewis Hills. A profile from the bottom of Lewis Canyon to the summit of the Big Level is shown in Figure 8.

The tributaries of Lewis Brook flow in V-shaped incisions in the bottoms of U-shaped valleys. Heads of these tributaries and tributaries

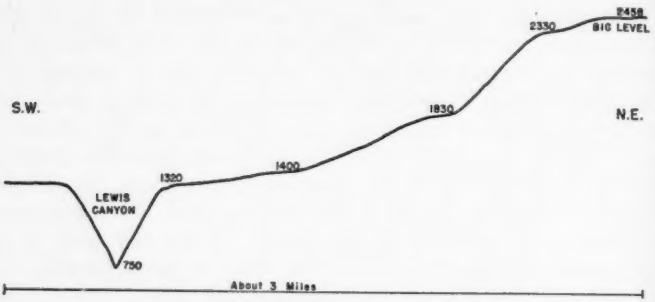

FIGURE 8.—*Profile of surface in Lewis Hills*
From the summit of the Big Level to the bottom of Lewis Canyon. The high level from 2330 to 2458 should be noted.

to them are hanging with waters cascading from the 1300 to 1700-foot level. The canyon of Lewis Brook is V-shaped in the bottom of a U-shaped valley. The V is 500 feet deep, or 500 feet below the 1300 to 1700-foot level where the authors crossed it. At its head, Lewis Canyon passes into a broad, flat-floored low area which merges into the broad valley at the foot of Rabbit Mountain. The elevation at the place of merging is estimated at 1100 to 1200 feet.

There thus seem to be three well-marked erosion levels in the Lewis Hills: (1) a high level of remarkable flatness with elevation above 2300 feet; (2) a well-preserved mature surface at 1300 to 1700 feet; and (3) a surface shown by upland valleys at elevations of perhaps 700 to over 1100 feet.

The physiographic development of the Lewis Hills is thought to have been about as follows:

(1) Development of a late mature surface of subaerial erosion, graded to sea level, on what is now the Big Level at 2330 to *2458* feet. This surface is thought to correlate with the summit level of the southern Long Range Plateau.

(2) Rejuvenation to permit development of the mature erosion surface that now forms the 1300 to 1700-foot level. There may have been a stillstand episode for a time during the rejuvenation to account for the terrace at 1830 feet. The surface produced after rejuvenation was

more or less gently rolling with broad valleys rising to rounded hills. This level is thought to correlate with the high valleys of the southern Long Range Plateau.

(3) Further rejuvenation and incision into the 1300 to 1700-foot level by streams that formed broad valleys whose bottoms are now 700 to perhaps 1200 feet above sea level. These valley levels are thought to correlate with the 1000 to 1100-foot level of the southern Long Range Plateau.

(4) Elevation followed by glaciation which at first extended over the entire area and was lastly confined to the valleys.

(5) Disappearance of the ice and cutting of V-incisions in the bottoms of those valleys that carried much water, as was the case of Lewis Brook, but not the wide valley at the foot of Rabbit Mountain.

It is thought that the Lewis Hills during a late phase of Wisconsin glaciation had its own ice cap with the main collecting grounds, particularly in the later stages, on the 1300 to 1700-foot level. The ice is thought to have been very thick and to have drained into the valleys of Fox Island River and Serpentine Brook, where it met glaciers originating in the mountains to the east, and into the present Gulf of St. Lawrence where it met ice from the Blow-me-down Mountains and possibly from Labrador. Bluff Head at one time was completely covered by ice as shown by the impressive features of glacial erosion on its summit. The Big Level also seems to have been covered as there is evidence of plucking on its sides. However, no foreign erratics were seen on its summit, but such should not be present if, in the waning stages of the ice, there was movement downward from its summit. Foreign erratics were found to the elevation of 1830 feet (barometric).

BLOW-ME-DOWN MOUNTAINS

The Blow-me-down Mountains are composed of the same kinds of rocks as the Lewis Hills and are a part of the same intrusive complex (Cooper, 1936). The mountains were climbed on the northeast side from the little bay at the mouth of Blow-me-down Brook. The trail leads over a wide lowland terrace that is about 60 feet above sea level at the shore and rises gently inland. There is a gentle ascent from this terrace to a 700 to 1000-foot level that is rather persistent over the south side of the Bay of Islands region. This is thought to correlate with the level of the wide valleys in the southern Lewis Hills. The slope from the 700 to 1000-foot level to the upland surface of the mountains is steep. The upland (1350 to 1700 feet barometric) is a gently rolling, old age surface with many lakes and swamps which rises from the low places of 1330 to 1400 feet to rounded hills that are 1600 to

1700 feet high (Pl. 3, fig. 2). Rattler Brook flows on this surface in a postglacial V-incision, 50 to 100 feet deep, which is cut in a wide, open, gently sloping preglacial valley. The waters of this brook cascade from the escarpment from an elevation of about 1350 feet.

Mt. Blow-me-down (*2135* feet) has a rounded to flat summit as seen obliquely from an airplane. The top of the mountain is a remnant of the same erosion surface of which the Big Level and Mt. Barren in the Lewis Hills are other remnants.

The same conditions thus are present in the Blow-me-down Mountains as on the Lewis Hills. There is a high level at *2135* feet, a mature gently rolling area at 1300 to 1700 feet, and a level of lower elevation in the range from 700 to 1000 feet. Seen from a distance these surfaces are extremely conspicuous. Above is Mt. Blow-me-down with rounded mature summit, below is the more extensive 1300 to 1700-foot level with relatively even sky line, and lower down is the 700 to 1000-foot level. The physiographic development was evidently like that of the Lewis Hills.

NORTH ARM MOUNTAIN

North Arm Mountain (Fig. 1), north of the North Arm of the Bay of Islands, is composed of a part of the Bay of Islands intrusive complex. On the Geologic Map of Newfoundland this intrusive body is continuous with Table Mountain on the south side of Bonne Bay, but Ingerson (1935) has shown that North Arm Mountain is separated from Table Mountain by a lowland area underlain by sedimentary and volcanic rocks belonging to the Humber Arm series of the Ordovician. The lowland was originally determined by a fault (Ingerson, 1935) and it is now occupied by Trout River Pond. A map by Ingerson (Fig. 9) shows an area on the summit of North Arm Mountain 2000 feet above sea level that is 7 miles long from northeast to southwest and 4.5 miles wide from northwest to southeast. The summit area thus covers about 25 square miles. Seen obliquely from the air this area is very flat. It is an excellently preserved large remnant of a plateau. The highest recorded elevation is 2314 feet. There may be higher places.

ST. GREGORY HIGHLAND

St. Gregory Highland (Fig. 1) is west of North Arm Mountain and adjacent to the coast. The highest elevations are Mt. St. Gregory (2226 feet G. M. N.) and Mt. Gregory (2240 feet G. M. N.). The map by Ingerson (Fig. 9) shows that only a small area is more than 2000 feet high and that most of the highland is between 1000 and 2000 feet. Seen from the air the summit is plateaulike, and the high summits are rounded. These summits are evidently remnants of a plateau.

TABLE MOUNTAIN, BONNE BAY

Table Mountain (Fig. 1) rises abruptly from a level that is 500 to 1000 feet high (Pl. 3, fig. 1; Pl. 4, figs. 1, 2). The map by Ingerson (Fig. 9) shows that the area on its summit higher than 2000 feet is

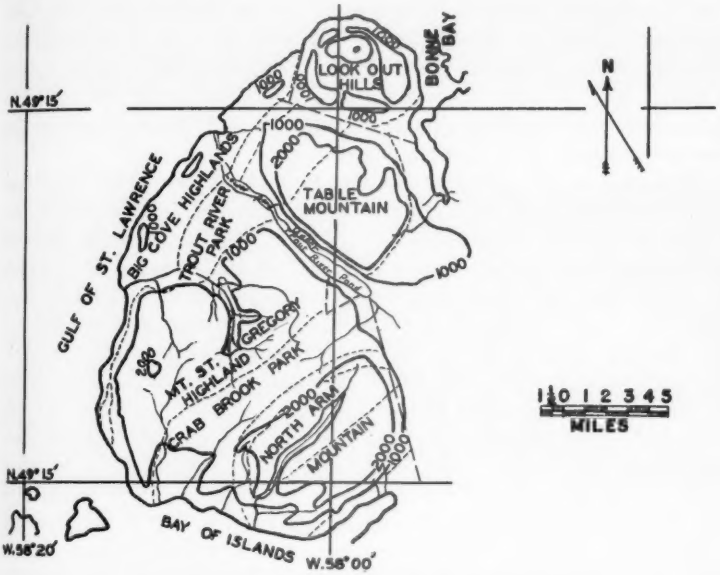

FIGURE 9.—*Bay of Islands "Serpentine" Range*
Between Bay of Islands and Bonne Bay. Redrawn from Figure 2 of Ingerson (1935, p. 425).

6 to 7 miles long and about 5 miles wide, or between 20 and 30 square miles. The summit is evidently a large remnant of a once extensive plateau. Table Mountain is separated from the adjacent Lookout Hills to the north by a wide, flat-floored low area that follows a fault. The northern part of this low area is occupied by a brook that is hanging at 500 feet and drains in a succession of rapids and falls into Bonne Bay. Southwestward, the low area is occupied by a tributary of Trout River. The divide is 520 feet high (barometric). This divide is about 1.5 miles from Bonne Bay and several times that distance from Trout River. The low area of which the divide is a part rises northeastwardly to the northeast margin of Table Mountain to an elevation of 800 to 1000 feet and is drained by the brook flowing into Bonne Bay. The slopes bordering this low area are steep, particularly on the Table Moun-

tain side where some are vertical cliffs. Glacial erosion is responsible for this steepness. Tributaries from Table Mountain to the streams flowing through this low area head in cirques, and there are hanging valleys from the Lookout Hills from heights of about 800 to 1200 feet. The cliffs or steep slopes to the top of Table Mountain are 1000 to 1500 feet high from the floor of the low area. Cirque floors in the mountain are around 1200 to 1400 feet above sea level, and this level seems to correspond to an erosional surface more or less excellently shown in the Lookout Hills where it appears to have a relief of about 200 feet. It is assumed that this level represents the 1300 to 1700-foot level in the mountains south of the Bay of Islands.

The edge of the Table Mountain Plateau at the place ascended (northwest side) is 2000 feet high (barometric) and inland toward the center it rises to above 2300 feet. The highest part on the plateau determined with barometer (certainly not the highest point on the plateau) was 2220 feet. The highest recorded point is 2336 feet (G. S. N.). The rise from the edge of the plateau is very gentle, and, except for the abundant rock fragments that cloak the entire summit (felsenmeer), the surface is not unlike that of a Kansas prairie. Relief in many places is not apparent, and what one sees is often an illusion. One may look ahead and have the impression that the surface is rising in the distance. He goes to the supposed higher place and looks backward to the place from which he came and it seems to be the higher. There is little or no organized drainage on this upland except where it is indented by canyons and cirques. There are no trees; much surface is barren, either bare rocks rounded to roches moutonnées, frost-riven blocks derived from the rocks of the mountain, or entire or broken erratics among which quartzites and granites of several varieties are common. The entire summit unquestionably was overridden by a thick glacier which disappeared comparatively recently.

LOOKOUT HILLS

The Lookout Hills (Fig. 1) are north of Table Mountain on the southern side of the entrance to Bonne Bay. The major part of the upland area is a dissected plateau remnant in the range of elevation from about 1100 to 1400 feet with some places rising above 1400 feet. The highest point, known as the Lookout, is *1988* feet. All parts have been glaciated.

Considered together, the Lookout Hills and Table Mountain exhibit three erosional levels, as do the other mountains of the Bay of Islands Range. There is the high plateau level with elevation exceeding 2000 feet, a lower dissected plateau in the range of elevation from 1200 to

FIGURE 1. AIRPLANE PHOTOGRAPH OF TABLE MOUNTAIN, BONNE BAY
From north side. Elevation at edge of escarpment 2000 feet. Upland area above 2000 feet has area of around 25 square miles.

FIGURE 2. AIRPLANE PHOTOGRAPH OF TABLE MOUNTAIN, BONNE BAY
From east side. Edge of escarpment 2000 feet above sea level.

FIGURE 3. ABOUT HEAD OF WESTERN BROOK POND
Surface 2000 feet or more above sea level. From the east.

FIGURE 1. HIGH VALLEY PENEPLAIN
About Main Topsail (1822 feet). Underlying rock and most erratics coarse-grained granite. Surface around 1500 feet above sea level. Part of the high Central Plateau.

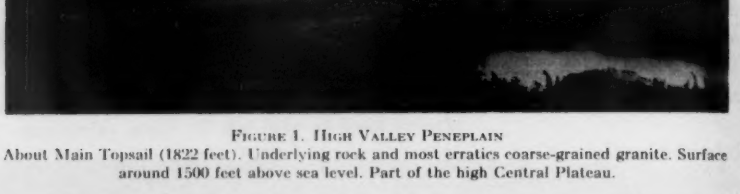

FIGURE 2. MIZZEN TOPSAIL (1762 feet)
Top and surrounding region and most erratics composed of coarse-grained granite. Surface around 1500 feet above sea level. Part of the High Valley Peneplain and High Central Plateau.

FIGURE 3. LAWRENCE PENEPLAIN AT BUCHANS
Monadnock is remnant from the High Valley Peneplain. Underlying rock various, much drift covered.

HIGH CENTRAL PLATEAU AND BUCHANS

perhaps 1600 feet, and a high valley level from about 500 to more than 1000 feet.

LONG RANGE MOUNTAINS

LOCATION

The Long Range Mountains (Fig. 1) lie east of the Bay of Islands "Serpentine" Range from the Lewis Hills to Bonne Bay but directly face the Gulf of St. Lawrence north of Bonne Bay. They present a more or less bold escarpment on the west, particularly north of Bonne Bay, and decrease in elevation to the east. They are part of the Long Range Plateau. The western front in the north has been shown by Dunbar to be the locus of a great overthrust fault. The Long Range Mountains are narrow from the Bay of Islands to Bonne Bay, and somewhat wider from Bonne Bay north. This upland surface is considered by districts.

HUMBER ARM, BAY OF ISLANDS

General description.—The Bay of Islands (Fig. 1) branches inland into North, Middle, and Humber arms. Each of these is very deep, and all were evidently deepened and had their sides steepened by glacial erosion when they were the channels of glaciers moving from the interior into the Gulf of St. Lawrence. The Bay is a composite fiord of three arms. Cross profiles show U-shaped valleys whose rims rise about 1000 feet above sea level and whose bottoms are 500 to 700 feet below sea level. The deepest sounding, 732 feet, is in Middle Arm.

The rocks about the Bay of Islands consist of limestones, various sedimentary clastics, various volcanics, and some rocks assigned to the pre-Cambrian. Much of the region rises to levels of 700 to 1000 feet as may be seen on Mt. Moriah, Limestone Mountain, and hills back of the town of Corner Brook. Higher elevations are shown in Mt. Musgrave (*1790* feet). The region is considered in the two areas of Corner Brook and Steady Brook, the former flowing into Humber Arm at its head and the latter into the Humber River, a few miles above its mouth.

Corner Brook area.—Corner Brook in its lower course flows in a gorge that extends from the town to the water supply reservoir, a distance of about 2.5 miles. This gorge lies in a wide, open valley that is 250 to 300 feet above sea level at the Bowaters Farm and some of the other areas back of the town.

There is no gorge above the water supply reservoir. The stream flows in a wide, open valley which near the reservoir has a flat floor at about 500 feet (barometric) above sea level. The floor of the valley gradually rises, and near the sixth milepost on the road to St. Georges Lakes

attains an elevation of around 1000 feet (barometric). The topography at this elevation is decidedly mature with some elevations rising to the east to an estimated height of around 1500 feet. According to Mr. A. C. Mason, Lake Corner Brook, on one of the tributaries of Corner Brook, is 950 feet above sea level and is in a valley substantially below the general level of the surrounding country of which the summits attain elevations of around 1500 feet, and a "high barren" mountain near the source of the brook rises to *2110* feet. It seems obvious that the wide, open valley of Corner Brook, ranging in elevation from 500 feet at the water supply reservoir to 950 feet at Corner Brook Lake and to around 1000 feet on the road to St. Georges Lakes, was produced during one erosion cycle. This cycle is represented on the flat summit of Mt. Moriah (625 feet), on the flat summit of Marble or Limestone Mountain, and the hills southwest of Corner Brook town where the summits attain elevations of 860 feet (barometric).

Steady Brook area.—The Steady Brook area, several miles inland from the head of Humber Arm, is on the south side of Humber River. What is said also applies to the north side, and the erosion level in the range of elevation from 500 to 1000 feet is more or less excellently shown on both sides of Humber Valley.

Steady Brook Valley "hangs" from a level of about 700 feet and descends to the floor of the Humber Valley in a succession of rapids and falls. Steady Brook above the rapids and falls has a very mature lake-dotted valley which gradually rises to an elevation that exceeds 800 feet and probably attains 1000 feet. The margining areas have summit levels rising to elevations of 1400 to 1500 feet with a few points rising to higher elevations. One of these is Mt. Musgrave (*1790* feet). This is a high peak overlooking the Humber Valley from the west side of Steady Brook. The summit area is small and excellently rounded except on the side toward Corner Brook where glacial plucking has taken place. The summit may be a remnant of the high upland level of the Bay of Islands Range. Other high peaks of the Steady Brook area have summits of similar appearance, and all reach about the same elevation. Erratics and roches moutonnées are present on the summit of Mt. Musgrave and, together with rock basin and moraine-dammed lakes, are numerous over surrounding areas. All glacial features have fresh appearance, and there has been little erosion since disappearance of the ice.

Ascent from the Humber Valley to the summit of Mt. Musgrave is steep to the elevation of about 1200 feet. The rise is then fairly gentle to about 1350 feet, followed by a steep rise to about 1500 feet. This

is the upland surface of a dissected plateau from which there is a gentle rise, modified by glacial plucking, to the summit of Mt. Musgrave (Fig. 10). By contrast the slope from Corner Brook to the 1200-foot level is gentle and then steep to the summit of Mt. Musgrave. The slopes

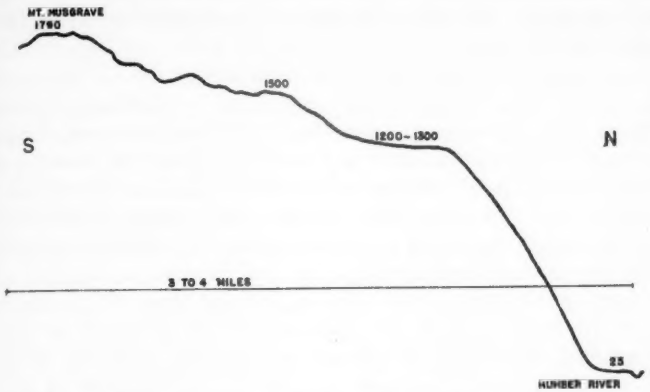

FIGURE 10.—*Profile from floor of Humber Valley to summit of Mt. Musgrave*

The surface from 1500 feet to the summit of Mt. Musgrave represents a dissected upland of what is termed the Atlantic Upland Peneplain. The steep slope from the floor of the Humber Valley is due to glacial oversteepening.

on the Humber River side are due to glacial oversteepening, and the cliffed slope of Mt. Musgrave toward Corner Brook is due to glacial plucking.

The physiographic development of the Humber Arm region of the Bay of Islands is thought to have been about as follows:

(1) Development of the upland surface that is now the dissected plateau at the elevation of about 1500 feet. The surface was then some 1200 feet lower than at present. This level is thought to correlate with the 1300 to 1700-foot level of the Lewis Hills and the Blow-me-down Mountains. Mt. Musgrave is a remnant of glacial erosion of a high point on this upland level.

(2) Elevation sufficient to permit cutting of the wide, open, mature valleys of Corner and Steady brooks and the generally mature slopes of the margining areas. This level ranges in elevation from 500 to 1000 feet.

(3) Elevation to permit cutting of a level 200 to 300 feet above sea level, making the gently sloping areas in this range of elevation on the hills back of Corner Brook.

(4) Invasion or accumulation of ice sheets which completely covered the region. The Humber Valley was then an important channel of movement of ice from the interior.

(5) Deglaciation with submergence followed by uplift giving rise to the marine and delta terraces present in Humber Arm and the Bay of Islands generally. The gorges in the lower reaches of Corner and Steady brooks were then cut.

BONNE BAY TO DEER LAKE

Bonne Bay (Fig. 1), like the Bay of Islands, is a submerged U-shaped valley of which the upper rim is about 1000 feet above sea level and the bottom is several hundred feet below sea level, the deepest place being in East Arm at 750 feet. Also, like the Bay of Islands, it is a composite fiord. There are two branches, known as the South Arm and longer East Arm, the latter extending entirely through the highest part of the Long Range Mountains into the lower country to the east where it is continued in the mature valley of Lomond River. The submerged part of the valley, or East Arm, has steep slopes; inland from the head of East Arm the valley is flat-floored and generally bordered by mature slopes.

A trail (road under construction) extends from Lomond, on East Arm of Bonne Bay and on the east side of the high mountains of the west coast, to Humber Arm and Deer Lake in the Grand Lake-White Bay Basin. The surface over the 32 miles of trail is in late maturity. The uplands have gently sloping to flat tops, which usually, if not always, are lower than 1000 feet. Valleys are wide with gently sloping sides. The country is only moderately hilly, and considerable parts of the surface are covered with drift which generally seems to be thin as bed rocks are extensively exposed. The divide between the Bonne Bay and Humber drainages is 12 to 13 miles from Lomond and is 790 feet (barometric) above sea level. Three other divides on this trail have elevations from east to west of 600, 750, and 680 feet (barometric).

Summit levels from Lomond eastward are thought to correlate with the 700 to 1000-foot level of the Bay of Islands region, and these uplands can be followed along the west side of the Humber Basin into the Humber Arm region. The uplands are maturely dissected and sharp features are generally wanting. There is another level in the range from 400 to 500 feet that is characterized by wide open valleys with many lakes. This level may owe its appearance to glacial erosion and deposition.

LONG RANGE PLATEAU NORTH OF BONNE BAY

The Long Range Plateau is continued north of Bonne Bay for over 50 miles and is splendidly shown in large remnants rising to the same

approximate elevations. The summits of the uplands are impressive in their flatness.

Gros Morne (*2651* feet), on the north side of Bonne Bay, is a conspicuous flat-topped plateau remnant with steep sides. The steepness is due to the work of glaciers which at some time in the Wisconsin stage completely covered the summit. The writers did not climb this mountain, but it was climbed by Professor R. F. Flint who states that erratics are present on the summit and that the summit has been glaciated.

Inland from Bonne Bay, and 10 to 15 miles from the head of White Bay, is Silver Mountain (*1504* feet), a peak considerably isolated from the other high mountains of the west coast. This mountain was not studied, but its elevation is significant.

North of Bonne Bay and Gros Morne are Mt. Tucker (*2452* feet), Mt. Baker (*2614* feet) at the head of Bakers Brook, and, a little farther north, Mt. Sally (*2441* feet). The summits are evidently plateau remnants of the 2000-foot level of the western mountains. Farther north are the high, flat-topped mountains about Western Brook Pond, a lake drained by Western Brook. Western Brook Pond (Fig. 1) lies in a U-shaped valley with a magnificent cirque at its head. Cliffs rise 2000 feet above the water to the flat-topped summits of the upland. Summits (2278 and 2300 feet, G. M. N.) seen obliquely from the air are strikingly flat (Pl. 4, fig. 3). Farther north about the head of St. Pauls inlet are splendid plateau remnants with elevations of 2047 and 2086 feet (G. M. N.). Seen from the air the summits are extremely flat. Inland from Parsons Pond, about 15 miles north of St. Pauls Inlet, the plateau rises very abruptly from the lowlands to elevations of *2198* and *2067* feet at two triangulation stations. At Portland Creek, about 15 miles farther north, the plateau is a little over 2000 feet (G. M. N.) high. The authors have no information as to the character of the upland surface.

F. C. Foley made a traverse from Hawke Bay on the west side of the Great Northern Peninsula across the Long Range Mountains to Great Harbour Deep on the west side of White Bay. Great Harbour Deep is over 50 miles north of the south end of the Bay. He reports that the summit of the Long Range Mountains is a dissected plateau which is a remnant of an ancient peneplain. The highest determined elevation was 2033 feet, but it was noted that some hills are at least 100 feet higher. The nearly flat summits are evidently remnants of a plateau. The authors have no information on the high uplands north of this traverse.

SUMMARY OF EROSION LEVELS IN THE WESTERN MOUNTAINS

The more or less flat-topped summits of the highest mountains of western Newfoundland are remnants of an uplifted peneplain. Present altitudes of the summit levels are around, and usually a little greater than, 2000 feet as is shown by Table 1.

TABLE 1.—*Altitudes of high plateau remnants in the western mountains of Newfoundland*

Figures in italics were acquired from the Geodetic Service of Canada through the courtesy of Mr. W. M. Dennis. Others were taken from the Geologic Map of Newfoundland, a map prepared by the International Power and Paper Company, or were given by the Geological Survey of Newfoundland.

	Feet
Long Range at Tompkins	2016
Long Range at South Branch	*1823*
Anguille Mountains	*1759*
Big Level on Lewis Hills	*2458*
Barren Mountain, Lewis Hills	2314
Mt. Blow-me-down	*2135*
High Barren, near head Corner Brook	*2110*
Stone Mountain, North Arm Mountain	*2314*
Mt. Musgrave	*1790*
Mt. St. Gregory	2226
Mt. Gregory	2240
Table Mountain, Bonne Bay	2336
Lookout Mountain, Bonne Bay	*1972*
Gros Morne	*2651*
Baker Mountain, head of Baker Brook, north of Bonne Bay	*2625*
Tucker Mountain, north of Bonne Bay	*2452*
Mountains of Western Brook Pond	2278
Mountains of St. Pauls Inlet	2037
Mountains east of Parsons Pond	2170
Divide between Hawke Bay and Great Harbor Deep	2000-2100+

Some remnants of this uplifted peneplain are 20 square miles or more in area, and remnants have been seen over a distance exceeding 200 miles. This is the oldest erosion level.

A second level is shown in the high upland valleys or dissected plateaus at elevations of about 1500 feet but with range of elevation from about 1300 to 1700 feet. These have been seen from Tompkins to Bonne Bay. The level is probably present in the Anguille Mountains. This level records a surface in late maturity and is that of a partial peneplain.

A third erosion level is present in the range of elevations from about 500 to 1000 feet. This has also been seen from Tompkins to Bonne Bay. This erosion level did not attain the same degree of maturity as did the other two, except on some areas of weak rocks where conditions of late maturity were reached.

The last erosion cycle is now in progress, but between this and the third there have been stillstands in which erosion cycles were begun but interrupted before a great deal of erosion had been accomplished. One such stillstand is shown in the lower reaches of Corner Brook, and others are shown by the marine terraces on the coast and the submerged valleys of Bay of Islands, Bonne Bay, and other indentations of the coast.

GRAND LAKE-WHITE BAY BASIN

The Grand Lake-White Bay Basin (Fig, 1) lies east of the western mountains and extends from the entrance of White Bay to the south end of Grand Lake. White Bay is a drowned part of the Basin. This lowland owes its origin to faulting that took place at some time in the Paleozoic, probably before the Mississippian, and later became filled with Mississippian and Pennsylvanian sediments. These were later deformed and differentially eroded to reduce the surface below the bordering areas. The lowland was an important channel during the Ice Age for movement of ice from the central part of Newfoundland. Morainic deposits are extensive from Howley to White Bay, and some are thick. Glacial erosion oversteepened the sides of the basin, particularly on Grand Lake and White Bay, and probably produced some deepening. Except where glacial erosion has modified the surface, the topography is mature, valleys are wide and slopes are gentle. The divide between White Bay and Sandy Lake drainages is near Rushy Pond, about halfway between White Bay and Sandy Lake, at an elevation between 530 and 600 feet (barometric). Elevations of bedrock surface between White Bay and Sandy Lake are not known, and the drift over parts of the divide seems thick. Bedrock surface over this part of the basin may not be more than 400 to 500 feet above sea level. The lowland area merges on the west side into that of Deer Lake. It is bordered on the east side by the escarpment of the High Central Plateau. Mt. Sykes and Mt. Seemore are spurs of the escarpment with respective elevations of 1013 and 1280 feet (G. M. N.).

The surface of the upland on the east side of the head of White Bay is 500 to 700 feet (barometric) above sea level. Further north elevations rise to around 900 feet. The upland surface is very gently rolling, little dissected, and bevels slates, argillites, and schists with inclined to vertical structures. The surface may correspond to bedrock elevation on the divide between White Bay and Sandy Lake and certainly corresponds to some exposures on the sides of the lowland area. The slopes rising to the upland are steep. The corresponding upland on the west side of the head of the bay is considerably dissected. The break in the slope from steep to gentle at the place ascended is at the elevation of about

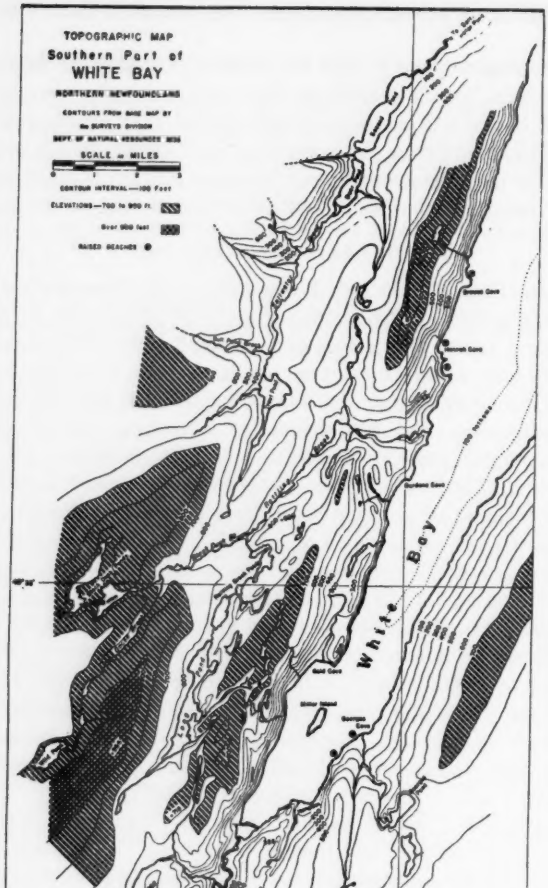

FIGURE 11.—*Topographic map of region about head of White Bay*

Unpublished. Prepared by the Geological Survey of Newfoundland. This map shows the relatively even surface of the upland in the range from 500 to 700 feet. The bottom of the head of White Bay is shown to be narrow and the surface on each side of the bay rises steeply to the upland areas in the range from 500 to 700 feet.

480 feet, approximately the level of the hanging valleys at that place, although some "hang" at about 250 feet.

The highest elevation measured (550 feet barometric) was found on top of a hill a mile or more inland from the edge of the steep escarpment. As seen from the top of this hill, adjacent summit levels are about the same elevation, and all summit levels seem to be accordant to a plane that rises slowly to the west. Farther north the upland level is around 700 feet with some hills rising to over 900 feet. The steep sides of White Bay are referred to erosion by a glacier which moved northward through the lowland. Figure 11 is a topographic map of the head of the White Bay and bordering areas made by the Geological Survey of Newfoundland. This shows the White Bay depression, the upland level, and the oversteepened slopes from the bottom of White Bay to the upland levels. High places inland from the bay range from about 900 to 1000 feet. These are considered to represent the high valley levels of the western mountains.

Farther south the uplands bordering Grand Lake seem to show two erosion levels—one around 1500 feet and the other about 1000 feet or somewhat less. The bottom of Grand Lake is stated to be 300 feet below sea level. This was either cut by fluvial erosion when Newfoundland stood at higher elevation or the deepening was done by a glacier. If due to fluvial erosion, there should be continuation of the erosion channel either down the Humber Valley or into White Bay. Neither seems likely. The distribution of rock exposures in the channel of the Humber, just above where it empties into the Bay of Islands, and also about the head of White Bay, seems to preclude outlet at either of these places. Erosion by a glacier seems to be the more likely explanation.

Disregarding the highlands of the High Central Plateau and the western mountains, the Grand Lake-White Bay Basin has three erosion levels of which one is the floor of the basin, a second is shown on the 500 to 700-foot upland surface on both sides of White Bay and may be shown on the bedrock elevation of the divide between Sandy Lake and White Bay, and the third is shown by hills on the upland surface in the range of elevation of 900 feet or more.

CANADA BAY

Canada Bay (Fig. 1) is near the north end and on the east side of the long northern peninsula of Newfoundland. The region has been described by Betz (1939) who has also prepared a topographic map. Betz states that there is a highland area on the east side with hills ranging in elevation from 450 to 700 feet. This highland area is bordered on the west by a lowland area which is 150 to 250 feet high. These two areas are

cut on Cambrian and Ordovician sedimentary rocks. On the west side is an area underlain by pre-Cambrian igneous terranes where elevations rise to 900 to 1100 feet. The surface is described as moderately irregular. Steep slopes are confined to the shores or to fault lines. An accordance of summit levels is suggested at an average elevation of 500 to 600 feet.

HIGH CENTRAL PLATEAU

GENERAL STATEMENT

The High Central Plateau is defined as that part of the Atlantic Upland between the Grand Lake-White Bay Basin and a line extending from Hall Bay to the head of Red Indian Lake. The division is made for convenience of description.

The area is described in four parts, as follows: (1) area bordering the railroad, (2) area along transmission line from Howley to Buchans Mines (3) north coast from Baie Verte to Hall Bay, and (4) southern part to the Atlantic Ocean.

The High Central Plateau rises abruptly from the Grand Lake-White Bay Basin to elevations that vary with locality but are 1300 to 1500 feet about Grand Lake, around 1000 to 1200 feet in the north, and 800 to 1200 feet in the extreme north. It is most easily reached via the railroad, and what is thought to be the most impressive part of this plateau is adjacent to the railroad. The surface of the plateau slopes to the east and apparently also to the north. Elevation to the southwest seems to range from about 1200 to 1700 feet.

HIGH CENTRAL PLATEAU ALONG THE RAILROAD

The surface of the High Central Plateau along the railroad is very gently rolling to flat with few irregularities other than some glacially modified monadnocks and some due to quarrying by ice. The area is a large remnant of a little dissected, glaciated peneplain. It is dotted with numerous lakes and swamps and abundantly strewn with large and small, remarkably fresh erratics. Roche moutonnée features are abundant. Most of the surface consists of broad open areas without steep slopes. Streams are almost without valleys, and the country above the streams does not seem to rise more than 50 to 150 feet above the highest point on the railroad (Summit, 1550 feet, G. S. N.). The streams wander more or less aimlessly over the surface as would be expected on old age fluvial topography modified by glaciation (Pl. 5, figs. 1, 2). The surface falls eastward from Summit, becoming 1274 feet (G. S. N.) 3.5 miles east of Summit and 7.5 miles from Gaff Topsail, the most western station on the Plateau.

Rising from this plain are monadnocks (termed Inselberge by Schrepfer) of which those best known and most easily reached from Gaff Topsail Station are the "Topsails" (Fig. 1), known respectively as Main Topsail, Mizzen Topsail, Gaff Topsail, and Fore Topsail. Main Topsail is the most conspicuous.

Main Topsail (*1822* feet) (Pl. 5, fig. 1) is an elongate crag on top of a low ridge. The crag is 250 to 275 feet higher than the ridge, and the ridge rises 25 to 50 feet above the general surface. The crag is elongated in a direction N. 66° W. The sides of the crag are essentially vertical, except on the southeast, where it may be climbed. The steepness of the sides of the crag are very clearly due to glacial plucking. The top is nearly flat over the northwest half and exhibits pronounced plucking features over the other half. Small glacially eroded depressions contained water on July 28, 1939. The width is about 100 feet, the length 400 to 500 feet. It is composed of coarse-grained granite, and the same rock underlies the region for at least half a dozen miles. Erratics of fresh rock are common on the summit.

Mizzen Topsail (*1762* feet) (Pl. 5, fig. 2) is composed of the same type of rock as Main Topsail. It may be climbed on all sides except the south where it is vertical. Splendid sheet jointing is present which from a distance simulates stratification. This jointing is inclined to the south. Orientation is parallel to the jointing.

Both Main Topsail and Mizzen Topsail before the Ice Age were probably high places on the High Central Plateau and they probably had graded slopes. The jointing in the granites facilitated plucking and led to their becoming crags. A longer time of glacial erosion would probably have led to their disappearance.

The High Central Plateau at Mary March, a station 12 miles east of Gaff Topsail, is gently undulating as far as one can see, though the elevation decreases consistently from Summit. The railroad from Mary March follows a broad, gently sloping depression which is the valley of Mary March Brook. The sides of the valley rise very gently to rounded, very mature hills. The summits of these hills correlate with the surface of the High Central Plateau. The valley floor is broad, tree-covered, and of low gradient and it passes without noteworthy change of elevation into the valley of Joe Gloads Brook which heads in a lake at Millertown Junction (689 feet G. S. N.) which is separated by only a short distance and not much of a col from another lake that drains north into Hall Bay. The High Central Plateau level is thought to have been almost completely removed from the area of Millertown Junction. A remnant of it is thought to remain on the summit of the Skull Hill monadnock (*1359* feet), 6 to 7 miles east of Millertown Junction.

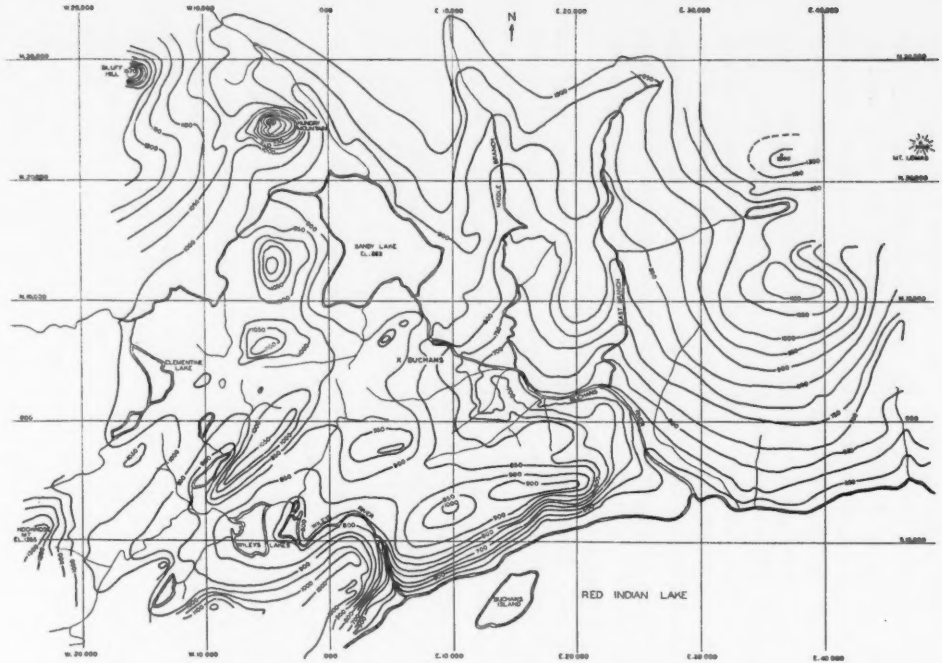

FIGURE 12.—*Topographic map of the Buchans Mining District*

Shows the rolling upland in the range from about 800 to 1000 feet and the monadnocks which rise several hundred feet above the general level. The very high monadnocks may be remnants of the Long Range Peneplain; most are remnants of the High Valley Peneplain. Redrawn from a map received from Mr. P. W. George of the Buchans Mining Company, Lim. A photograph of this surface taken from a position south of Sandy Lake and looking toward Buchans is shown in Figure 1 of Plate 5. Distances between vertical and horizontal lines in feet.

This hill has a rounded summit and oversteepened sides. Another elevation whose summit may correlate with the surface of the High Central Plateau is near Gull Pond, about 10 miles north of Millertown Junction. This is *958* feet high.

AREA ALONG TRANSMISSION LINE, HOWLEY TO BUCHANS ON RED INDIAN LAKE

The transmission line rises from the Grand Lake-White Bay Basin, on which Howley is situated, to a broad nearly flat area known as the Hines Lake Flats. This is 800 to 1000 feet above sea level. There is a fairly gentle slope from Howley to the upland level which begins at about the elevation of 800 feet and rises slowly to 950 feet about 8 to 9 miles east of Howley. This surface then extends to Buchans on Red Indian Lake.

The region at the latter level is fairly flat; bottoms of the valleys are at about 800 feet, and gentle slopes rise to the highest points which seem to be in the range of 900 to 1000 feet. To the north and northeast are the higher levels of the High Central Plateau (about 1400 feet) above which the monadnock known as the Lobster House rises to *1916* feet. Pointed Hill, east of Lobster House, is *2155* feet high. To the south are the Notched Mountains (1555 feet, G. M. N.), and still farther south are the Halfway Mountains (1400 feet, G. M. N.). The summits of Notched and Halfway mountains are thought to represent the High Central Plateau; those of Lobster House and Pointed Hill may represent the 2000-foot level of the western mountains.

Incisions of streams into the Hines Lake Flats have been so slight that a succession of lakes and swamps still exists. Incisions have been made toward Howley and, as noted later, on the edge of Red Indian Lake. The surface everywhere proves late glaciation.

The 800 to 1000-foot level between Howley and Buchans represents a stillstand stage in the erosional history which must have been quite long if one may judge from the subdued character of the surface.

BUCHANS MINES

Buchans is near the north end of the west shore of Red Indian Lake. The upland surface is even to gently rolling with isolated monadnocks rising 150 to 500 feet above the general level of 900 to 1000 feet (Pl. 5, fig. 3). Some monadnocks have steep sides; most have relatively gentle slopes. The region has been strongly glaciated, and much detail is due to deposition connected with melting of ice. The level of about 900 to 1000 feet has mature aspect from which the monadnocks rise and below which the surface descends to the lowland in which Red Indian Lake is situated (Fig. 12). The surface of the lake is about 500 feet above sea level, and the depth is about 300 feet, making the elevation

the High Central level. The very high monadnocks may be remnants of the High Valley Peneplain; most are remnants of the Long Range Peneplain; most are remnants of the High Valley Peneplain. Redrawn from a map received from Mr. P. W. George of the Buchans Mining Company, Ltm. A photograph of this surface taken from a position south of Sandy Lake and looking toward Buchans is shown in Figure 1 of Plate 5. Distances between vertical and horizontal lines in feet.

of the bottom about 200 feet. The basin is very old, was once filled with Paleozoic strata, and its present depth is due to erosion of these rocks. The basin was probably originally produced by faulting. Its depth below the surrounding country is probably to be ascribed to glacial erosion.

The 900 to 1000-foot level is considered to be the eastward continuation of the Hines Lake Flats, and the summits of the monadnocks probably to correlate with the surface of the High Central Plateau.

The physiographic development of the region from Howley to Buchans is thought to have been about as follows:

(1) The peneplain of the High Central Plateau was first formed when the land was much lower than now.

(2) Uplift of the order of magnitude of 400 to 500 feet permitted erosion to a new level that is now represented in the late mature surface of the Hines Lake Flats.

(3) Additional uplift initiated the cycle that permitted carving of the basin of Red Indian Lake. This erosion cycle was interrupted by glaciation.

(4) Glaciers scoured the surface, steepened the slopes of some monadnocks, and made additions to the depth of the Red Indian Lake Basin. The basin was probably an important channel of ice movement.

(5) Disappearance of the ice left the surface nearly as it is now, the only important modification being the eroding of V-shaped incisions in the bottoms of valleys adjacent to Red Indian Lake.

BUCHANS JUNCTION TO MILLERTOWN JUNCTION

The railroad follows the valley of Demascuit or Mary March Brook from Buchans Junction (550 feet) to Millertown Junction (689 feet), a rise of 139 feet in 20 miles. This valley is a succession of lakes, and the margining areas are very gently rolling. Obviously the surface of this valley is a continuation of the same valley west of Millertown Junction, and it was carved during the same erosion cycle. It is also a continuation of the upland surface around Buchans.

THE NORTH COAST

Baie Verte.—Baie Verte (Fig. 1) is on the north coast of Newfoundland on the east side of the peninsula that limits White Bay on the east. The upland surface was studied at Deer Cove, near the east side of the entrance of Baie Verte, and on McKay's Lookout near the head of the bay. The bay is a fiord as are most bays on the north coast of this part of Newfoundland.

The valleys at Deer Cove "hang" at about 50 to 60 feet above sea level, above which they are flat-floored for a mile or so before rising to

higher elevations. The hills, composed of altered volcanics, diorite, and serpentinized rocks, rise to about the same heights. Summits are gently rounded, of considerable extents, and most are between 540 and 700 feet high. The larger valleys on the upland surface are wide and contain glacial lakes. Most have steep sides, and some head in cirques. The surface is much dissected with relief of 300 to 400 feet adjacent to the sea and less with distance therefrom.

McKay's Lookout, a prominent hill on the west side of the head of Baie Verte, is relatively steep-sided, particularly near the top, and is 680 feet high (barometric). It has been isolated by erosion from larger elevated areas to the south and west which appear to rise to 750 to 800 feet. The upland surface is mature with wide flat-floored valleys, in the lower reaches of which 10 to 20-foot V-incisions have been eroded. The high upland surface is thought to correlate with the upland surface of the High Central Plateau.

St. John Peninsula (Fig. 1) separates Baie Verte from Notre Dame Bay. The hills on this peninsula were seen from a boat, and the coastal maps show them to be around 500 feet high. They have flat to gently rounded summits and accordant summit levels. According to Snelgrove (1931), the plateau area about Tilt Cove on the east side of St. John Peninsula is nearly 500 feet above sea level. The plateau surface is dissected and marked by low parallel ridges which are surmounted by rounded hills of which none seems higher than 800 feet above sea level.

Kings Point.—Kings Point is situated at the head of the Southwest Arm of Green Bay, about 25 miles northeast of Mt. Sykes (1013 feet, G. M. N.) on the western margin of the High Central Plateau and over 30 miles southeast of Tilt Cove. The upland surface has accordant summit levels at around 500 to 600 feet with some elevations rising to around 700 feet. Inland and eastward from the head of the Arm elevations attain around 1000 feet (G. M. N.). These are considered remnants of the High Central Plateau.

Little Bay.—Little Bay, an indentation from Green Bay, is situated on the west side of Notre Dame Bay. Observations were made on the tops of the hills north of the village near the head of the bay. The hills are steep-sided, terraced about the base, round-topped, and have accordant summit levels in the range of 500 to 700 feet.

Springdale and New Bay.—Springdale is situated near the head of Hall Bay. A hill of volcanic rock back of the village is 480 feet (barometric) high. This elevation accords with that of other hills on both sides of Hall Bay. Summits are rounded and glacially eroded. Some high

elevations southwest of the head of the bay are *1006* and *1018* feet high. New Bay, the first deep bay west of the estuary of Exploits River, has an elevation near its head that is *1004* feet high. These are considered remnants of the High Central Plateau.

Summary.—Two levels may be identified on the north coast; one is around 1000 feet high, and the other 500 to 700 feet high. The higher level is correlated with the surface of the High Central Plateau, and the lower with the level of Hines Lake Flats and Mary March Brook.

SOUTHERN PART OF HIGH CENTRAL PLATEAU

The southern part of the High Central Plateau passes around the southern end of Grand Lake to unite on the southwest with the Long Range Plateau and around the south end of the Annieopsquotch Mountains to connect with the country to the southeast and east of Red Indian Lake. Available information indicates that the region south of Grand Lake has a gently rolling upland surface at elevations of 1400 to 1500 feet. Some of this was seen from the air, and the surface resembles that of the Topsails region. The Annieopsquotch Mountains are 2043 feet (G. M. N.) high. Red Indian Lookout, near the foot of Red Indian Lake, is 1875 feet high (G. M. N.), Halfway Mountain, near the middle of the west side of Red Indian Lake, is 1400 feet (G. M. N.), and southwest of Annieopsquotch Mountains are places that are 1640 and 1901 feet (G. M. N.) high. There is no certainty of the accuracy of any of these figures. The High Central Plateau level should be around 1400 feet. It is assumed that places rising above this level are monadnocks and remnants of the 2000-foot level of the western mountains.

On the south side of Newfoundland and just east of the middle reaches of the La Poile River are the Blue Hills of Couteau with elevations of 1903, 1740, 1690, 1670, and 1170 (G. M. N.) feet. These figures are of questionable accuracy. A figure obtained from the Geological Survey of Newfoundland places the elevation at 1500 feet. The Geological Map of Newfoundland gives elevations of places west of the entrance of La Poile Bay as 850, 1060, and 1128 feet. These figures may need some correction.

A summary of the little known southern part of the High Central Plateau suggests that the surface may fall into three ranges of elevation as follows: (1) elevations exceeding 1500 feet which represent monadnocks, (2) surfaces of 1400 to 1500 feet and somewhat less on the east which represent the peneplain surface of the High Central Plateau, and (3) surfaces that are 1000 feet in height or less which correspond to the Hines Lake flat and Mary March Brook levels.

SUMMARY OF HIGH CENTRAL PLATEAU

Scattered over the High Central Plateau are monadnocks that rise to more than 2000 feet. Most have their present appearance because of glacial plucking and before the Ice Age most were probably graded to the surface of the plateau. It is suggested that the summits of the highest are remnants of the 2000-foot level of the western mountains.

The plateau surface is around 1000 feet high on the north, around 1400 to 1500 feet along the railroad in the Topsails region, about 1200 feet on the west side of Red Indian Lake, and 1400 to 1500 feet on the south end of Grand Lake.

A third erosion level is that of the Hines Lake Flats and Mary March Brook. This is 500 to perhaps 800 feet on the west end of the north coast and around 500 feet on Hall Bay. It is 800 to 1000 feet on Hines Lake and at Buchans, 550 feet at Buchans Junction, 689 feet at Millertown Junction, and around 1000 feet at the head of Mary March Brook.

NOTRE DAME BAY EAST OF HALL BAY, AND THE EXPLOITS VALLEY

INTRODUCTION

Most of this region is a part of a lowland that extends from the south end of Red Indian Lake to Notre Dame Bay. The lowland is underlain by Paleozoic sandstones and other clastics with associated basic igneous rocks. The lowland is largely due to the easily eroded Paleozoic strata.

MILLERTOWN

Millertown is situated on the Red Indian Lake lowland on the east side of Red Indian Lake about 8 miles from the north end. Water level in the lake is maintained at about 500 feet by a dam where the Exploits River leaves the lake. Above the lake a gently rolling surface rises to a maximum of 700 to perhaps 750 feet above sea level. Monadnocks rise 500 to 600 feet higher. Among these are Hungry Hill (1220 feet), 7 to 8 miles south of Millertown; Harpoon Hill (about 1200 feet), also known as Lake Ambrose Mountain, near Lake Ambrose and about 25 miles south of Millertown; Higgins Lookout in the same general region as Harpoon Hill; and Mt. Joshua on the east side of Red Indian Lake. All of these seem to be at about the same elevation. The streams on this rolling surface flow in very wide and very shallow valleys, and some seem to have no valleys at all, only shallow channels on a nearly level surface. Exploits River, where it leaves Red Indian Lake, has a very shallow channel (about 450 feet above sea level) in a wide, open valley. A few widely separated monadnocks rise fairly gently to about 800 feet, above which they become steep and in some places vertical. These

slopes are more or less due to glacial deposition about the bases and glacial plucking in the upper parts. They have remained because of resistance of the composing rocks.

It is thought that the level of the High Central Plateau is represented to some degree on the summits of the monadnocks which underwent some erosion below original levels during the Ice Age. The rolling surface that makes up most of the lowland around Millertown is correlated with the surface of Hines Lake Flats and Joe Gloads and Mary March Brook.

BADGER TO HALL BAY

East of Skull Hill, a considerably dissected surface extends to the very flat and wide area through which the Exploits River flows with very little indication of a valley. This flat wide area begins about 8 miles west of Badger and extends eastward to the mouth of the Exploits River, but a valley has developed between Badger and Grand Falls and this gradually deepens downstream to a depth of about 200 feet at the mouth of the river.

Badger (317.5 feet, G. S. N.) lies on a very wide and flat plain that extends to the limits of visibility. The Exploits River flows through this plain in a very shallow channel, and the surface of the river is only a few feet below the level of the plain. There are a few low hills of which those examined are composed of glacial drift.

The surface rises toward Hall Bay (Fig. 1) very gradually from the 317.5 feet at Badger to 635 feet high (barometric) about 14 miles north of Badger. This surface contains many lakes and swamps and bed rock was not seen over the 14 miles. The surface then slopes very gently to the north to 450 feet (barometric) about 20 miles north of Badger. North of 20 miles the road follows a valley of mature aspect to Hall Bay. This valley has a very extensive flat area at the elevation of 260 feet (barometric) and another at 170 feet (barometric).

The upland surface thus ranges in height from 317.5 feet at Badger to 635 feet 14 miles north of Badger. Some of the flatness is due to the cover of drift. It is thought that this extensive nearly level surface correlates with the tops of the hills around Hall Bay and is the geomorphic equivalent of the surface of the valley of Mary March Brook and the Hines Lake Flats.

PILLEYS ISLAND AREA

The Pilleys Island area is situated between Hall Bay on the west and Badger Bay on the east. Espenshade (1937) reports an upland surface with elevation of 200 to 300 feet. This has gently rolling areas a mile or so in extent above which there rise small elevations.

GRAND FALLS

Grand Falls (Fig. 1), 18 miles east of Badger, is 248 feet (G. S. N.) above sea level at the railroad station. The station is above the town, and back of the station are low ridges that are about 25 feet higher than the station, or at an elevation of 273 feet. This level is a continuation of the extensive plain at Badger where it is 317.5 feet high. The Exploits flows in a trench that has its floor 50 feet below the station. The Exploits channel in this trench is a small canyon cut in bedrock below the falls. Bedrock has extensive exposures on the walls and sides of the trench.

A monadnock, known as Red Cliff and composed of basic igneous rock, is about 5 miles west of Grand Falls. This rises to about 560 feet (barometric) out of a nearly level erosion surface that is around 250 feet above sea level. Red Cliff is a remnant of higher land to the north that rises 100 to 200 feet (estimated) above the summit of Red Cliff in broad rounded ridges. This upland surface seems fairly well dissected with wide shallow valleys with gently sloping sides. It is considered the correlate of the High Central Plateau surface. The plain from which Red Cliff rises is quite certainly the eastward extension of the Mary March Brook level.

HODGES HILLS

Hodges Hills, situated a little north of half way between Grand Falls and Badger, are a group of hills rising to an elevation of *1868* feet from a 600 to 800 feet upland surface. The hills are composed of basic igneous rocks. The Hodges Hills were not climbed but were seen from a distance of a few miles. The rounded summits testify to their having been glaciated. Slopes to the south are relatively gentle, those to the north seem stepped. The summit of this monadnock is correlated with the summits of the high monadnocks on the High Central Plateau; the level of the High Central Plateau is thought to be present about the base of the hills in the elevation of around 800 feet.

BISHOPS FALLS

The floor of Exploits Valley or Trench at Bishops Falls (Fig. 1) is 43 feet above sea level and 160 to 170 feet below the very level upland surface. The bottom of the trench is indented by the channel of the river which is steep-sided below the falls and very shallow above. The bottom of the trench is a quarter to half a mile wide and is pre-Wisconsin. The slope of the north side of the trench rises with moderate steepness for about 70 feet and then with more gentle slope to an elevation of about 160 feet and thence over a surface of shallow depressions and low ridges to 210 feet above sea level at a point about 2 miles north of the

edge of the trench. The surface at this level is very flat, is cut on Silurian sandstones, and extends almost to the limits of visibility in all directions. The surface is extensively swampy, contains many erratics of a wide lithologic character, and has little local relief. There are occasional shallow drainage areas and subdued variations in elevation (Fig. 13). The elevations are probably composed of drift. Two high hills are

FIGURE 13.—*Profile across the Exploits Trench at Bishops Falls*

Shows the Lawrence Peneplain on both sides of the Trench.

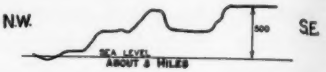

FIGURE 14.—*Profile at Norris Arm from the Lawrence Peneplain to sea level*

visible in the direction of Botwood, and 10 to 20 miles to the west is the high monadnock of Hodges Mills (*1868* feet).

BAY OF EXPLOITS

The region of the Bay of Exploits (Fig. 1), has been studied by Heyl and Twenhofel and Shrock. Heyl (1936) states that

"A considerable portion of the Fortune Peninsula (the peninsula on the west side of the Bay of Exploits) is an upland surface, only slightly dissected and then only adjacent to the sea coast. It is best developed north and west of Lawrence Harbor where its altitude is approximately 200 feet."

Heyl designated this upland surface the Lawrence Peneplain and stated that it is present on the Loon Peninsula and southward on the mainland. The same surface with approximately the same elevation may be seen on the New World Island and Fogo Island. Thwart Island in the Bay of Exploits is *357* feet high, and elevations of about 400 feet are present on Fogo Island.

BOTWOOD

Botwood, on the Estuary of the Exploits River, is on a peninsula between Northern Arm and Peters Arm. Hills composed of rhyolite or sandstone, up to 200 feet high, lie immediately back of the town. The upland surface on these hills is very mature. This same surface may be seen across Northern Arm, where, however, there is a higher level in the range from 400 to 500 feet. Slopes rising to these upland levels are gentle.

NORRIS ARM

Norris Arm (Fig. 1) is an appendage of the Exploits Estuary. The village of the same name is on the south side of the Arm. A steep hill back of the village is composed of basic igneous rocks which seem to have fault contact with the dark shales that underlie the lowland on which the

village is built. The factor immediately responsible for the steep slope is the weakness of the shales in relation to the stronger igneous rocks. The upland above the steep slope is more or less gently undulating with general accordance of summit levels at about 250 feet above sea level. Brooks on the upland are in shallow depressions. Rising above the 240-foot upland are rounded knobs that range between 400 and 500 feet high; most appear to be about 450 feet or a little less. These have been rounded by glacial erosion, and many show plucking phenomena. About a mile inland from the edge of the steep slope are somewhat continuous hills of about the same elevation as the knobs (Fig. 14).

Two erosion levels seem to be present in the Bay of Exploits area—one between 200 and 300 feet above sea level and the other between 400 and 500 feet above sea level. The lower seems to be the Lawrence Peneplain of Heyl, and it correlates with the Mary March Brook erosion surface.

SUMMARY

Two erosion levels seem to be present in the Red Indian Lake-Exploits Valley-Notre Dame Bay region. The highest is shown only on the monadnocks and has elevation that is around 1200 feet in the Red Indian Lake region, 700 to 800 feet west of Grand Falls, and perhaps 400 to 500 feet around Notre Dame Bay. The second is the rolling upland east of Red Indian Lake at an elevation of 500 to 700 feet. This falls to less than 350 feet at Badger, is about 275 feet at Grand Falls, and a little more than 200 feet at Bishops Falls and on Notre Dame Bay. The highest level correlates with the surface of the High Central Plateau, and the lower seems very clearly to be the northeastward extension of the Hines Lake Flat-Mary March Brook level. The entire region has been glaciated with glacial and fluvial-glacial deposits very extensive locally. Outwash deposits, exposed above the head of Peters Arm, were originally very extensive, but erosion has reduced them to remnants of which some are considerable hills.

EASTERN PART OF ATLANTIC UPLAND TO PLACENTIA AND TRINITY BAYS

GENERAL STATEMENT

This part of the Atlantic Upland is considered under the three divisions of (a) Baie d'Espoir region and coast west, (b) Atlantic Upland south of the railroad, and (c) area along the railroad.

BAIE D'ESPOIR REGION AND COAST WEST

The Baie d'Espoir (Fig. 1) is a deep embayment on the south coast of Newfoundland west of Fortune Bay. The underlying rocks belong to

the Baie d'Espoir series of Jewell (1939) and are doubtfully assigned to the Silurian. Jewell states

"The topography of the Baie d'Espoir area consists essentially of a relatively flat upland ('Barrens') varying from 800 to 1200 feet above sea level with an average altitude of about 1000 feet.

"The 'Barrens' upland is extremely flat in a broad way, and the skyline is uniform and regular. In detail, however, this surface is extremely rough and broken. There are practically no continuous ridges or 'flats,' especially in the areas underlain by granites.

"The 'Barrens' upland unquestionably represents an uplifted peneplain and is a part of the old erosion surface described as making up most of the interior of Newfoundland."

The region has been extensively glaciated, but there is no evidence of more than one ice advance. At first there was a large ice cap that extended to the sea, and later there were individual ice tongues that occupied the larger valleys and fiords and maintained connection between the central ice and the sea.

West of the Baie d'Espoir, there is a continuous succession of upland areas ranging in elevation from less than 700 feet to a little more than 1000 feet. These seem to be highest about 20 miles west of the entrance to the Baie d'Espoir where an altitude of 1525 feet is attained, and several elevations range in altitude from 1220 to 1440 feet (G. M. N.). These elevated areas evidently represent continuation of the "Barrens" westward, and the particularly high places are evidently monadnocks on the "Barrens" upland. The "Barrens" upland is considered a continuation of the surface of the High Central Plateau.

ATLANTIC UPLAND SOUTH OF RAILROAD

Not a great deal is known of the Atlantic Upland south of the railroad. Published maps show it to have many lakes, to be the headwaters of many streams, and to have isolated elevations rising from 1200 to 1644 feet. The most extensive elevation seems to be Middle Ridge, a northeast-southwest trending upland about 25 miles long and about 40 miles south of Notre Dame Junction. The height of this upland is not available other than that Murray and Howley state that the southwest branches of Gander River rise among the most elevated peaks at altitudes a little less than 1000 feet (Murray and Howley, 442). Other elevations (G. M. N.) are Mt. Cormack (1200 feet), about 35 miles south of Badger; Partridgeberry Hills (1253), 45 miles south and a little west of Grand Falls; Burnt Hill (1113 feet, railroad map), northeast of Partridgeberry Hills; Mt. Peyton (1581 feet), a little east of south of Norris Arm and 5 to 6 miles west of Gander Lake; and Mt. Sylvester (1250 feet, G. M. N.), about 40 miles south of the head of Fortune Bay.

Mt. Peyton has been seen by the senior writer only from a distance. It is a conspicuously high point on a northwest-southeast trending

ridge which rises from a general elevation estimated to be in the range from 600 to 800 feet above sea level.

These high places are considered remnants of the eastward extension of the High Central Plateau, and the lower level is thought to be the Lawrence Peneplain.

AREA ALONG THE RAILROAD

The area along the railroad extends in a northwest-southeast direction from the isthmus between Placentia and Trinity bays to Norris Arm. The area is described from east to west as that is the way it was seen.

Just west of the middle part of Trinity Bay and about 7 miles northeast of Come-by-Chance is Centre Hill with an elevation of *1133* feet. Partridge triangulation station, west of Northern Bight and north of Placentia Bay, is *935* feet high. These hills are evidently monadnocks on the general upland surface of 400 to 500 feet and correlate with such places as Mt. Peyton and Mt. Cormack.

At Clarenville a flat-topped hill composed of rhyolite rises steeply from the marine terrace on which the village is situated to 500 feet. The upland surface is nearly level, is dotted with lakes and swamps, and has leisurely wandering streams which fall over cliffs or flow down steep slopes to reach the sea. Larger valleys cut into this surface, such as Shoal Harbor Brook and the stream about a mile east of Clarenville, have broad floors and steep sides.

The upland surface on the railroad is 400 feet high at the head of Shoal Harbor Brook. A hill that is *978* feet rises from this level. There is a level to gently sloping surface at 425 feet just east of Thorburn Lake between the 141 and 142 mile posts, and a similar surface is 345 to 455 feet high just east of Thorburn Lake station. The Geodetic Service of Canada gives three elevations south of Clode Sound and east of Port Blanford of *591* (Sweet), and *692* (Popes) and *755* (Clode). These seem to be high points on the 400 to 500-foot level.

The upland surface is 375 feet high at the 157 mile post, 465 near 159, and 425 at the 161 mile post. The country from 147 to 161 mile posts is very flat to gently rolling. Near Terra Nova the strikingly flat upland surface is 400 to 500 feet high. High places on this surface are East base (*508* feet), Five Mile (*690* feet), and Terra Nova (*709* feet) triangulation stations.

Terra Nova River is broad, has a shallow, low-banked channel, and hardly any valley.

The upland level from mile post 166 to 182 ranges from 360 feet near mile post 178 to 500 feet near mile post 168 and at Maccles near mile post 176. At most places this surface is close to 400 feet. The surface

south of the railroad rises a little higher. Near Broad Cove, about 10 miles east of Maccles, the high point is *654* feet, and near Maccles a high point at *690* feet. The Alex triangulation station near Alexander Bay, 181 mile post, is *680* feet high. The elevation of the surface from 185 to 196 mile posts ranges from 120 feet at 187, except 60 feet at Gambo Pond, to 240 feet at mile post 207. The surface is *444* feet high near Wing Point, about 20 miles northeast of the east end of Gander Lake. There is a high point of *681* feet near Benton, on the east end of Gander Lake, another of *469* feet near Fourth Pond, north of the east end of Gander Lake, and one of *695* feet just south of Gander Lake.

Beginning at mile post 207, the surface rises to the 400-foot elevation, being 320 at 207, 340 at 208, 209, and 210, and 410 at the Newfoundland Air Port at 213 mile post; this last elevation is maintained to the 218 mile post. The country in the vicinity of the Newfoundland Airport is remarkably flat.

Beginning at the 220 mile post, the surface falls to around 200 feet and continues on that level to the 228 mile post where it drops to 110 feet at Greenwood station. It is again at 200 feet at 234 mile post, and at Notre Dame Junction the elevation is 244 feet. The 200-foot level can then be followed to Norris Arm and proven that it is the equivalent of the Lawrence Peneplain. The 200-foot level is very extensive and very flat, the chief departures being rounded knobs whose outlines are due to glacial erosion.

SUMMARY

It is obvious that two levels are present along this part of the railroad: one in the range from 200 to 500 feet and a second that rises to a maximum of about 1000 feet. The first corresponds to the 200 to 300-foot level on Notre Dame Bay and the Exploits Valley and higher altitudes on Mary March Brook. The level around 1000 feet, represented by Centre Hill and Partridge and Shoal triangulation stations, is correlated with surface of the High Central Plateau.

Farther south in the interior the level of the High Central Plateau is 800 to 1000 feet high. A lower mature level has not been determined, though it is probably present.

AVALON PENINSULA

The Avalon Peninsula is the southeastern part of Newfoundland. The western half of this peninsula seems to have its highest elevation (832 feet, G. M. N.) on a long northeast-southwest trending ridge composed of an acid intrusive. Near Bay Robert on the west side of Conception Bay is the Robert triangulation station (*838* feet). The Jones station at Jones Harbor on the east side of Trinity Bay is *818* feet high.

Most parts of the upland surface seem to be in the range of 350 to 500 feet.

The Butter Pot (955 feet, G. M. N.) is on the south end of the eastern half of the Avalon Peninsula. South of Holyrood, at the head of Conception Bay, are the Hawke Hills (955 feet, G. M. N.). East of Holyrood are other hills with range in elevation from less than 800 to over 1000 feet. Farther north, near Killigrews on the east side of Conception Bay, the Curren triangulation station is *835* feet high, and the Portugal triangulation station, opposite Bell Island, is *716* feet high.

South Base triangulation station, near Donovon on the railroad between Conception Bay and St. Johns, is *802* feet, and the Simpson station on the peninsula between Conception Bay and the Atlantic Ocean is *749* feet high. The Snelgrove station in the same general locality is *756* feet high. Ewbank, just north of St. Johns, is *486* feet, and St. Georges in the South Hills of St. Johns is *760* feet high.

There is a mature upland surface cut on upturned quartzite, quartzite conglomerate, and argillite on the South Hills of St. Johns. The triangulation station (*760* feet) is on a part of that surface. A few places are a little higher. There is another surface in these same hills at altitudes of 350 to 400 feet which is shown in valleys with mature slopes and gently inclined floors. This surface seems to be a part of the gently rolling surface that forms the uplands north of St. Johns. This rises to about 400 feet. The upper part of the city and the farmlands west and north of the city lie on a surface of little relief with elevation of approximately 200 feet.

There is an upland surface between St. Johns and Placentia Bay which at Avondale, about 36 miles west of St. Johns, is approximately 400 feet high. It is 390 feet high west of Avondale and rises to 460 feet just before dropping into Brigus Junction at 329 feet. Above this more or less level surface are rounded knobs and hills of which one at the fire tower, a mile east of Brigus Junction is around 600 feet high. The mature upland surface is 360 feet high at the 48 mile post, and on the divide, just east of Ocean Pond (265 feet), it is 325 feet. The upland valleys are wide and shallow, and some have V-shaped incisions 10 to 20 feet deep. Just beyond Placentia Junction, on the road to Placentia, the upland surface is about 450 feet high. Another upland surface is visible at this place. This is about 800 feet high and probably corresponds to the upland surface on the South Hills at St. Johns. Nine miles south of Placentia Junction the gently undulating upland surface is 420 to 450 feet high. This upland surface is crowded with lakes and swamps. A little farther south the railroad drops into a deep valley with steep sides and a U-profile.

There seem to be three erosion surfaces on the Avalon Peninsula. The lowest is around 200 feet high and is gently rolling. The second is 350 to 450 feet above sea level and is shown in very gently rolling uplands which seem to compose most of the peninsula. The highest is 700 to 800 feet above sea level and is preserved only on the highest parts of the Peninsula as the South Hills of St. Johns. Monadnocks rise in places above this level. Some of these exceed 1200 feet.

The 700 to 800-foot level is considered the eastward extension of the surface of the High Central Plateau. The 350 to 400-foot level is correlated with the Lawrence Peneplain and thought to be the eastward extension of the Mary March Brook-Hines Lake Flats level.

The entire surface of the Avalon Peninsula has been profoundly modified by glacial erosion. Erratics seem to be largely of local origin.

NEWFOUNDLAND PENEPLAINS

INTRODUCTORY STATEMENT

Use of the term peneplain requires definition. As originally defined by Davis, a peneplain is "a nearly featureless plain" produced by subaerial erosion. It is not a true plain but nearly always possesses "inequalities amounting frequently to two or three hundred feet." Local relief is understood. Considered broadly, upper and lower parts of drainage areas on peneplains may be expected to differ considerably in elevation above sea level, and the differences may exceed 1000 feet. Divides between streams may be 100 feet or more higher than bottoms of bounding valleys. Long profiles of streams may be expected to be at grade. Peneplains of little or no local relief and almost uniform local elevation should be rare, but land surfaces of which parts have progressed beyond the late mature stage of the cycle of erosion should be not uncommon features of the surface. These are partial peneplains.

It is thought that three uplifted mature to old age surfaces in the mountains of western Newfoundland may be designated peneplains in some stage of development. Only two have been identified in other parts of Newfoundland.

Recognition of peneplain surfaces in any single area of Newfoundland is not difficult, but there is considerable uncertainty with respect to correlation of the peneplains of one area with another. This arises from several causes. Different areas owe development to erosion by streams with different degrees of erosional efficiency and hence have different stages of development. Surface rocks of any large areas have different degrees of resistance to erosion and differences of relief result even if the erosive processes have uniform impact over the area. Headwater areas of stream valleys must necessarily be higher than near

mouths of streams, and they are also likely to lag in an erosive cycle. Lastly, uplift of a region as large as Newfoundland may be expected to be differential. All these factors were present in the formation of the upland surface of Newfoundland, and any peneplain surface should not be expected to have the same height and the same degree of development everywhere.

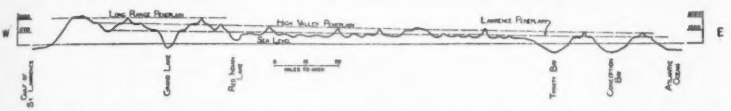

FIGURE 15.—*Profile from the Gulf of St. Lawrence south of Bonne Bay to the Atlantic Ocean at St. Johns*

Broken lines show correlation of the three peneplains.

The above facts make correlation difficult, and the almost total absence of topographic maps limits accurate correlation to tracing an erosional level from place to place. This has been done for only limited areas. All correlations must be considered provisional. Much more field work must be done before accuracy can be assured.

A profile drawn from the Gulf of St. Lawrence south of Bonne Bay to the Atlantic Ocean at St. Johns is shown in Figure 15. The surface of Newfoundland drawn to approximate scale is shown in the profile. The vertical is somewhat exaggerated. Dashed lines indicate correlations of erosional surfaces. The 2000-foot level of the western mountains is correlated with summits of high monadnocks on the High Central Plateau; the 1300 to 1700-foot level of the same mountains with the mature to old age surface of the High Central Plateau, the summits of the monadnocks on lowlands east of the High Central Plateau, and the summits of the "Barrens" upland around Baie d'Espoir; and the 500 to 1000-foot level of the western mountains with the 200 to 500-foot level of the north coast, the eastern part of the Atlantic Upland, and the Avalon Peninsula. Correlation of the summits of the high western mountains with the old age surface of the High Central Plateau was considered and rejected as it seems probable that the 1300 to 1700-foot level of the western mountains can be traced across Grand Lake to the High Central Plateau.

Description and correlation of peneplains is much easier if they have names. It is proposed to designate the 2000-foot level so excellently shown on the summits of some of the western mountains as the Long Range Peneplain, the 1300 to 1700-foot level present in the western mountains and much better developed on the High Central Plateau

as the High Valley Peneplain, and the 500 to 1000-foot level of the western mountains as the Lawrence Peneplain, a name proposed by Heyl for an upland surface of little relief about 200 feet above sea level on Notre Dame Bay. If correlations are correct, the lowest peneplain might better be named the Mary March Brook Peneplain, as it is splendidly developed in the valley of that stream, but the authors think it best to retain the name proposed by Heyl.

LONG RANGE PENEPLAIN

The upland level of the Long Range Peneplain has been described on earlier pages, and, if correlations be correct, the most extensive remnants are preserved on the summits of the Bay of Islands "Serpentine" Range and those of the northern part of the Long Range Plateau. This peneplain is thought to be represented on the High Central Plateau and east to the Atlantic Ocean by summits of some of the monadnocks of which those given in the following list are representative:

	Feet
McNeil triangulation station, south of Mt. Seemore	*1818*
Birchy triangulation station, near Mt. Seemore	*1846*
Main Topsail	*1822*
Lobster House	*1916*
Pointed Hill, east of Lobster House	*2155*
Annieopsquotch Mountains (G. M. N.)	2043
Blue Hills of Coteau (G. M. N.)	1901
Hodges Hill	*1922*
Mt. Peyton	*1581*
Mt. Sylvester (G. M. N.)	1250

The monadnocks are probably lower now than before the Ice Age, as the glaciers must have removed something from their summits. It is thought that there is little representation of the Long Range Peneplain over the eastern part of Newfoundland.

HIGH VALLEY PENEPLAIN

The High Valley Peneplain is represented in the western mountains by very broad upland valleys in the range of elevation from about 1300 to about 1700 feet. It forms much of the surface of the High Central Plateau which is 1400 to 1600 feet high on the west and declines to about 1200 feet in the vicinity of Buchans on Red Indian Lake. It is 700 to 800 feet high northwest of Grand Falls in the vicinity of Red Cliff, 800 to 1000 feet around the headwaters of the Gander River, averages 1000 feet in the region of the Baie d'Espoir, and 700 to 800 feet near St. Johns. It is largely represented by summits of more or less extensive erosion remnants over the Avalon Peninsula.

LAWRENCE PENEPLAIN

The Lawrence Peneplain was named by Heyl for a surface about 200 feet high that was described as having excellent preservation on the Fortune Peninsula (Fig. 1) between New Bay and the Bay of Exploits. This surface is thought to have been traced to become 500 to 1000 feet high in the High Central Plateau and the western mountains.

The Lawrence Peneplain is represented in the western mountains by flat-topped spurs on the escarpments at heights of about 1000 feet, by dissected uplands areas in the range from about 700 to 1000 feet. It makes the summit of Table Mountain at Port au Port, the 500 to 600-foot upland areas around White Bay, the lowland area followed by the transmission line from Howley to Red Indian Lake, and the broad valley of Mary March Brook with range in elevation from 500 to 1000 feet. It is 317 feet high at Badger where the extensive flat to gently undulating lands on both sides of the Exploits River belong to the surface. It decreases in elevation eastward to become about 275 feet at Grand Falls, around 200 feet at Bishops Falls, and the same altitude about the Bay of Exploits. It is about 400 feet high at the Newfoundland Airport, and that approximate height is maintained to St. Johns.

The three peneplains with altitudes are tabulated as follows:

Peneplain	Western Mountains	Avalon Peninsula
1. Long Range	Around 2000 feet	Above 1000 feet and destroyed
2. High Valley	1300 to 1700	700 to 800
3. Lawrence	500 to 1000	350 to 400

OTHER EROSION LEVELS

There are other erosion levels in Newfoundland, some of these have been noted. Information is not adequate to attempt correlation.

ORIGIN OF NEWFOUNDLAND PENEPLAINS

On preceding pages it has been assumed that the three postulated Newfoundland peneplains were formed by fluvial erosion. The hypothesis of marine origin was repeatedly considered in the field and rejected. Marine plains of erosion should bear features connected with the manner of their origin. They should terminate in features of shore erosion, they should have little local relief, they should be of the nature of broad terraces with consistent original decline in elevation from the shores toward the body of water responsible for their cutting, and they should not be furrowed by valleys of mature to old age aspect. The surfaces of the

Newfoundland peneplains are extensive, they bear no resemblances to marine terraces, there are no features interpretable as shore phenomena, they are furrowed with mature to old age valleys, and they have local relief up to 200 feet or more. These features seem incompatible with a marine origin and they are inevitable on a mature to old age surface developed by fluvial erosion. It must be assumed however, that each of the peneplains at one time was graded to a marine terrace, and in case of the latest peneplain care must be taken lest the features of the marine terrace adjacent to the present shores obscure the features of the peneplain inland from the shores.

TIME OF ORIGIN

The peneplains were formed before the Ice Age as all bear the features of glacial erosion wherever they have been seen. All truncate strata as young as the Ordovician, and the Lawrence Peneplain truncates Silurian and probably Carboniferous strata. If the strata of the Baie d'Espoir region are Silurian, as postulated, they are crossed by the High Valley Peneplain. Among the largest and best remnants of the Long Range Peneplain are those cut on Ordovician intrusives. It may be suggested that the peneplains are very old and have been exhumed by stripping of overlying strata. Foley's profile and section from Hawke Bay to Great Harbour Deep may be interpreted to suggest such a possibility, but there are few or no factual data on which such an assumption may be based. The basal part of the cover on the pre-Cambrian in the region studied by Foley is Cambrian, whereas in the Bonne Bay and Bay of Islands regions the Long Range Peneplain is later than the Ordovician and it is the same peneplain that is on the summit of the Long Range Plateau of northern Newfoundland. Moreover, any pre-Cambrian or pre-Ordovician peneplain of the western and central parts of Newfoundland would have been deformed and destroyed by the post-Ordovician orogeny.

The Silurian sediments of Newfoundland indicate great relief during that period, and these sediments were intensely deformed and intruded by batholiths in post-Silurian time. These facts are thought to preclude the view that the highest and oldest of the peneplains can be older than the Devonian.

Mississippian and Pennsylvanian strata are present from the Codroy Valley to Bay St. George, in the Grand Lake-White Bay Basin, and on Red Indian Lake; they may have covered intervening areas. However, the character of the sediments of these strata suggests derivation from areas of considerable relief and deposition after limited transportation, neither of which suggests deposition on a peneplain. The faulting along the west base of the Long Range Plateau was probably in

Permian time, and some of this faulting must have taken place before exhumation of a buried surface was possible. The available evidence suggests that the exhumed surface could not have been a peneplain. The facts thus suggest that there is no possibility of the oldest peneplain having been formed in the Paleozoic, buried beneath Paleozoic sediments, and exhumed in post-Permian time. These facts place the time or origin of the peneplains after the Permian and before the Ice Age.

The Long Range Peneplain has well-preserved large remnants. The High Valley and Lawrence peneplains have excellent preservation over large areas. The excellence of preservation suggests that formation took place in the latter part of the long period from the Permian to the Pleistocene. However, there is a possibility that the Long Range Peneplain may have been formed in an early part of this interval and was then buried under late Mesozoic or early Tertiary sediments and exhumed in late Tertiary. There is no evidence for this idea as there are no strata in Newfoundland from the Pennsylvanian to the deposits of the glaciers and there are no reasons for believing that such strata ever were present. It seems likely that the Long Range Peneplain was formed in the Tertiary, perhaps in the late Cretaceous. The cutting of the High Valley Peneplain would then have been of later Tertiary and the Lawrence Peneplain of still later time.

SUMMARY

1. Correlations presented in this paper are no more than provisional. The writers have made the correlations that seem most reasonable on the basis of existing information.

2. More or less extensive and well-preserved remnants of an old age surface in the western mountains are termed the Long Range Peneplain. It is suggested that this peneplain is represented on the High Central Plateau on summits of high monadnocks and has been almost completely destroyed over the Avalon Peninsula and the eastern part of Newfoundland.

3. High valley levels of late mature aspect in the western mountains with range in elevation from about 1300 to 1700 feet are correlated with the surface of the High Central Plateau which is 1400 to 1600 feet high on the west and declines to about 1200 feet at Buchans. This level is termed the High Valley Peneplain because of its excellent preservation in the western mountains. It is about 1000 feet high in the Baie d'Espoir region, and 700 to 800 feet at St. Johns.

4. A third level in the western mountains is in the range of 500 to 1000 feet. In the High Central Plateau this level is responsible for the mature surface over the lowland area from Howley to Buchans and the

broad valley level of Mary March Brook. It makes the mature upland areas of 500 to 1000 feet of the Grand Lake-White Bay Basin, the 200-foot level of Notre Dame Bay and the lower Exploits Basin, and the 350 to 400-foot level at St. Johns.

5. All peneplains are thought to slope to the east and all decrease in elevation in conformity with drainage.

6. The peneplains developed through fluvial erosion and they are not plains of marine origin.

7. The times of origin of the peneplains were in the Tertiary although it is possible that the Long Range Peneplain was formed in the late Cretaceous.

TABLE 2.—*Elevations at triangulation stations in Newfoundland*

(Provided by the Geodetic Service of Canada through courtesy of Mr. W. M. Dennis, Mr. Neil Ogilvie, and Mr. F. P. Steers.)

Station	Latitude and Longitude	Elevation (*Feet*)	Station	Latitude and Longitude	Elevation (*Feet*)
Saddle	47° 47′ 59 13	1206	Lewis	48° 50′ 58 29	2673
Lake	47 51 59 06	1240	Rocky	48 59 58 20	2502
Coal	47 54 58 59	1857	Blow-Me-Down	49 04 58 16	2135
Downey	48 01 58 44	1743	High Barren	48 46 57 55	2110
Barachois	48 11 58 41	647	Stag	48 50 58 07	1365
Robinson	48 16 58 48	311	Steady	48 56 57 50	1790
West Base St. Fintans	48 12 58 52	99	Gull	49 09 56 11	958
East Base St. Fintans	48 09 58 47	490	Hall	49 21 56 04	1018
Steel	48 23 58 25	1005	Bobs Hill	49 09 55 59	1006
Table	48 36 58 39	1185	Hodges	49 04 55 53	1868
Hare	48 39 58 07	1958	New Bay	49 10 55 31	1004
Big Level	48 46 58 31	2458	Lawrence	49 11 55 14	527

TABLE 2.—*Elevations at triangulation stations in Newfoundland*—Continued

Station	Latitude and Longitude	Elevation (*Feet*)
Thwart	49° 18′ 55 08	357
Peyton	48 57 55 06	1581
Loon	49 14 54 53	468
Gander	48 55 54 42	695
Fourth	49 02 54 28	469
Crown	48 50 54 22	681
Wing	48 57 54 10	444
Alex	48 41 54 04	680
Maccles	48 35 54 17	690
Broad	48 37 53 56	654
Terra Nova	48 29 54 08	709
Five Mile	48 33 54 04	690
East Base	48 30 54 02	508
Bruins	47 52 59 19	978
Codroy	47 54 59 12	1198
Northern	47 57 59 04	1482
Limerick	48 03 58 57	1759
Old Man	49 08 57 43	1628
Stone	49 15 57 59	2314
Erskine	48° 25′ 57 30	2200
Tucker	49 32 approx- 57 40 imate	2452
Lookout	49 32 57 58	1972
Gros Morne	49 26 57 47	2651
Baker	49 39 approx- 57 46 imate	2625
Sally	49 42 approx- 57 50 imate	2441
Silver	49 35 57 12	1504
McNeil	49 08 56 56	1818
Birchy	49 16 56 44	1846
Lobster House	49 02 56 57	1916
Pointed Hill east of Lobster House	49 00 56 56	2155
Mizzen Topsail	49 06 56 37	1761
Main Topsail	49 08 56 33	1822
Sheffield	49 14 56 33	1640
Skull Hill	49 00 56 15	1350
Parrons	49 57 57 32	2198
Arches	50 03 57 32	2067
Ochre	48 31 53 57	706

TABLE 2.—*Elevations at triangulation stations in Newfoundland*—Continued

Station	Latitude and Longitude	Elevation (*Feet*)	Station	Latitude and Longitude	Elevation (*Feet*)
Clode	48° 23′ 53 59	755	Portugal	47° 37′ 52 52	716
Sweet	48 26 53 41	591	South Base Donovon	47 29 52 51	802
Popes	48 17 53 44	692	Simpson	47 33 52 49	749
Shoal	48 11 54 02	978	Snelgrove	47 37 52 47	756
Centre	47 53 53 52	1133	Ewbank	47 35 52 40	486
Jones	47 59 53 44	818	St. Georges	47 33 52 42	760
Partridge	47 49 53 19	935	Signal Hill	47 34 52 41	498
Robert	47 36 53 23	838	Anguille	47 54 59 23	1026
Curren	47 29 52 58	735	Rosie	47 50 59 23	86

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WISCONSIN GLACIATION OF NEWFOUNDLAND

BY PAUL MAC CLINTOCK AND W. H. TWENHOFEL

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ABSTRACT

From the presence of fresh erratic stones and ice-scoured topography it is concluded that Newfoundland was completely glaciated during the Wisconsin stage of the Pleistocene. The glaciation had three recognizable episodes: (1) the maximum

episode, (2) the Bay St. George episode, and (3) the cirque-forming and local moraine episode. During the first of these, ice spread as a complete cap from the Long Range Plateau, the Central Plateau, and the Avalon Peninsula outward in all directions to beyond the present shore lines of the island. It overrode the Anguille and the Bay of Islands mountains. It rounded the uplands and gouged out the fiords. During the second episode the ice margins receded, and fossiliferous marine sediments were deposited. These marine sediments were in several places overriden during a readvance of the ice which in the Bay St. George area deposited a fairly stout and continuous moraine. During the third episode the ice had dwindled to local glaciers excavating cirques at the heads of valleys and building minor moraines such as those at South Branch and Kittys Brook. The land has subsequently risen so that the marine sediments are well above sea level. Evidence from raised and warped strand lines suggests that Newfoundland was completely glaciated by ice spreading from the Labrador center at the climax of Wisconsin glaciation.

STATEMENT OF THE PROBLEM

Interest in the glaciation of Newfoundland has continued from the days of the early geologic explorers down to Fernald, Coleman, and the present geologists of the Newfoundland Geological Survey. Opinion has varied on practically all details. Some have held that the island was glaciated by ice from the Labrador center, others that it supported only a local ice cap; some (Coleman, 1926, p. 203, 206, 220) complete glaciation during an early Pleistocene stage and only local glaciers in the lowlands and valleys in Wisconsin time; whereas others (Twenhofel, 1912, p. 18) have maintained that Wisconsin ice covered the whole island. The object of the study was to seek evidence upon which agreement might be reached to settle at least some of the major problems.

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workings and made available maps and diamond drill records. Mr. A. House conducted the writers around the quarry at Aguathuna. Most cordial and helpful contacts with the local people were experienced everywhere.

GEOLOGIC AND TOPOGRAPHIC SETTING

Newfoundland is composed dominantly of metamorphic and plutonic igneous rocks into which have been folded or faulted areas of volcanics and of Paleozoic sediments in northeast-southwest lineaments. These latter have been intruded in places by considerable masses of basic and ultrabasic rocks.

The whole area has been subsequently peneplained, rejuvenated, partially peneplained, rejuvenated again, partially peneplained again, and finally rejuvenated and slightly dissected to the topography as it was at the onset of glaciation. During the erosion which followed the initial rejuvenation the softer rocks were etched out to form the lowlands specified by Snelgrove (1939) as the West Coast Lowlands, Grand Lake-White Bay Basin, and Notre Dame Bay Basin. The resistant igneous and crystalline rocks stand as uplands such as the Long Range Plateau, the Indian Head Range, and the Bay of Islands "Serpentine" Range, as also do some of the resistant sedimentary rocks such as form the Anguille and the Table mountains at Port au Port. The bulk of the island is a plateau, with a series of outlying masses along the west coast, sloping gently from about 2000 feet above sea level in the west to about 700 feet on the east.

COMPLETE GLACIATION DURING WISCONSIN TIME

GENERAL STATEMENT

Since it would have been impossible in the available time to cover in detail the whole of Newfoundland it was decided to study (1) those places which Fernald visited and all those which Coleman (1926, p. 193-223) studied and described, and (2) as many other critical places as possible—*i. e.*, the tops of the highest mountains, especially those on the periphery of the island which would most likely not have been overridden by an ice sheet that covered only the interior of the island.

Altitudes were taken by Paulin altimeter. Bearings have been corrected for magnetic declination and are reported in this paper as true azimuth.

LONG RANGE PLATEAU AT TOMPKINS

Tompkins lies at the south end of the Codroy valley 22 miles north of Port aux Basques. The west scarp of the Long Range Plateau of crystallines rises sharply from Carboniferous sediments of the valley floor. The scarp is notched in its upper part by short U-shaped hanging valleys which head in cirques and evidently were shaped by late glacial ice. The top of

the plateau here presents a subdued rolling topography rounded and scraped by glaciation. Roches moutonnées in excellent preservation are abundant to an altitude of 1900 feet. At higher levels most of them are shattered by frost splitting. Innumerable glacial lakes dot the surface of the plateau. Between them insequent streams wander aimlessly. Postglacial erosion is negligible on the plateau except adjacent to its margin where ravines 50 to 100 feet deep are present above the cirques. Most lakes seem to be rock-rimmed but several are confined by drift. Erratics, unrelated to the underlying rocks, litter the surface, even to the tops of the highest of the round-topped summits. Many had been perched on outcrops in positions and circumstances such that only glacial ice could have been responsible. The erratics are normally fresh and firm. The surfaces, of course, are somewhat pitted and etched by frost, rain, and wind action. Every line of evidence points to a Wisconsin age for the glaciation.

LONG RANGE PLATEAU AT SOUTH BRANCH

Sharp ascent from the drift-covered Codroy valley reaches, at an elevation of about 1600 feet, a wide expanse of late-mature to old-age stream-cut plateau surface on which the higher gentle hills rise to 1700 or 1800 feet above sea level. The broad integrated valleys at 1600 feet are dotted with lakes (Pl. 1, fig. 1). The shallow ungraded streams wander aimlessly among the lakes. Numerous partly frost-riven roches moutonnées are present. Glacial erratics are abundant on hilltops as well as in valleys, perched on various kinds of rock outcrops or embedded in drift. Drift, bedrock, and erratics are all mechanically somewhat disrupted but very slightly decayed chemically. The glaciation of the whole upland was evidently no older than Wisconsin.

From a hilltop, at an elevation of 1750 feet, one mile south of the triangulation station, the view to the south across the plateau shows in the foreground the broad, flat, lake-dotted, ancient valley floor at an elevation of between 1640 and 1700 feet, below which is notched the cirque at the head of Stephens Brook, beyond this cirque the gently rolling plateau surface gradually rises to the high (2000 feet +) flat-topped surface near Tompkins. The view to the southeast includes as part of the 1600-foot level the divide whence ice spread westward to the Codroy valley and southeastward to the Atlantic Ocean. The view toward the east spans 20 miles of subdued, lake-dotted plateau to what appears through field glasses to be a serrate divide on the horizon.

ANGUILLE MOUNTAINS AT SOUTH BRANCH

All the way up the trail to the triangulation station numerous igneous erratics are seen embedded in drift or lying loose on the sandstone bedrock

of the mountain. The top is broad and flat, with several good-sized undrained depressions, two of which contain lakes. No cirques or U-shaped valleys attest to local glaciers. The mountains were evidently overriden by ice from an area where igneous rocks were available. The freshness of the erratics and the glacial topography again suggest Wisconsin glaciation.

LONG RANGE PLATEAU AT FLAT BAY BROOK

The plateau was climbed at Three Brooks on the south side of Flat Bay Brook and 10 miles southeast of St. Georges. The upland surface is gently rolling and shows every evidence of having been heavily glaciated by ice thick enough to round all the protuberances and to make lake basins and roches moutonnées. Most of the exposed surfaces of bedrock are littered with frost-broken fragments, but there are also numerous rounded erratic boulders of various kinds of igneous and metamorphic rock. The valley of Flat Bay Brook is U-shaped with precipitous side walls rising 1200 to 1500 feet above the floor. Many of the tributaries are likewise in U-shaped valleys which hang 200 to 400 feet above the main. Here at Three Brooks, a southeasterly tributary in a U-shaped lake-studded valley hangs 500 feet above a lower U-shaped lake-dotted valley which itself hangs 400 feet above Flat Bay Brook.

The top of Steel Mountain (Cairn Mountain) on the north side of Flat Bay Brook is also glacially rounded and smoothed and littered with erratics all hard and fresh.

INDIAN HEAD MOUNTAINS

The road west from Stephenville Crossing passes over the southern end of the Indian Head Range. Road cuts have exposed southwest-trending striae evidently made by ice passing out through Bay St. George. The till exposed is brownish from podsolization but as judged by the freshness of the gneissic and granitic pebbles it cannot be older than Wisconsin.

TABLE MOUNTAIN AT PORT AU PORT

The top of Table Mountain is composed of limestone. The topography is flat to gently rolling and holds two small lakes. The surface is mostly littered with frost-split slabs and blocks of native limestone. Where the limestone is massive, however, it has preserved roches moutonnées. Many erratic boulders and cobbles of granite, greenstone, gneiss, and schist are scattered about. One well-rounded pinkish granite measured 8 by 8 by 4 feet. All are sound and hard inside a frost-pitted shell a sixteenth of an inch thick. The presence of glacial topography and the freshness of the erratics unquestionably point to Wisconsin age of the glaciation. A brook on the west side of the mountain has a mature valley in the bottom of which is a postglacial V-shaped incision, 30 to 40 feet deep.

FIGURE 1. TOP OF LONG RANGE PLATEAU AT SOUTH BRANCH

FIGURE 2. ENTERING BONNE BAY, GROS MORNE IN THE DISTANCE

FIGURE 3. TABLE MT. BONNE BAY, SHOWING SMALL CIRQUES ON THE NORTH SCARP

FIGURE 1. TOP OF MAIN TOPSAIL, SHOWING ERRATICS

FIGURE 2. FROST-SPLIT ROCHE MOUTONNÉE, TABLE MT. BONNE BAY

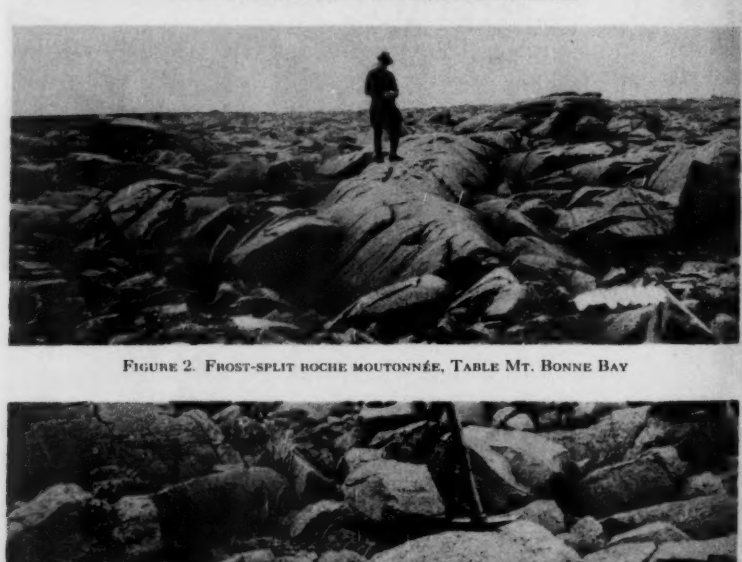

FIGURE 3. GRANITE ERRATIC AMONG THE FELSENMEER BLOCKS ON TABLE MT. BONNE BAY

THE BIG LEVEL, LEWIS HILLS

The ascent was made from Fox Island River across the drift-covered lowland and up the east slope of the mountain mass. Erratics were found to an elevation of about 1800 feet, and lakelets, irregular drainage, and roches moutonnées attest to glaciation at least to 1800 feet. From this elevation to the top of the mountain at 2358 feet the slope is so steep and littered with frost-broken bedrock that erratics would scarcely be expected. This slope has been smoothed, but occasional little cliffs without much talus are evidence of plucking. The top of the mountain is flat, perhaps half a square mile in area. It is covered by a thick felsenmeer of the native basic rock. No large erratics were found, but time did not permit a thorough search among the blocks of the felsenmeer for smaller ones. Descent was made on the south side where obvious glacial features were again found at 1400 to 1800 feet above sea level. The traverse then carried southwestward over several miles of the 1400-foot level and over Bluff Head. Obvious glacial features such as lakes, displaced drainage, roches moutonnées, drift, and erratics are abundant. Bluff Head showed a surprising dearth of foreign stones, though roches moutonnées are abundant. All seen were steeper on the south. Cooper (1936) suggested that this was evidence of glaciation by Labrador ice. This may be true, but the structure of the rock would have to be known much better to rule out the possibility of structural control. If the glacial shaping had been accomplished by Labrador ice, more and larger variety of erratics would be expected. All the exposures and stones are perfectly solid and fresh below a one-sixteenth inch layer of normal post Wisconsin weathering.

The lack of strong cirques and glacial erosion suggests possible thin local ice fields on the uplands. Lewis Brook Valley and the bordering areas to over 1700 feet were strongly glaciated and well may, as suggested by Cooper, at least in one phase of the glaciation, have carried ice from the east across the Big Level-Bluff Head massif out into Port au Port Bay on the west. This valley merits detailed study.

THE BLOW-ME-DOWN MOUNTAINS

Like the Big Level this mountain mass is composed of basic igneous rocks. Thus the presence of erratics of acid igneous rocks is conspicuous. Fresh, red quartz porphyry erratics looked just like those so common in the Wisconsin drift of Illinois and Wisconsin. A ridge of red granite lies west of Blow-me-Down, but the presence of similar erratics in Curling and east of Corner Brook suggests a source for all of them in the Long Range. Rock basin lakes and glacially rounded forms are present on every hand. Rattler Brook has cut a 50- to 100-foot V-shaped valley

during postglacial time. The topography here is very much like that of the Long Range Plateau. It was probably overrun by ice from the Long Range and possibly, during a late stage, became the collecting ground for a local ice cap.

LONG RANGE PLATEAU AT STEADY BROOK, HUMBER VALLEY

Ascent was made up Steady Brook to the Geodetic station on Mt. Musgrave (1790 feet). The upland here is rounded, lake-dotted, and boulder strewn. The summit of the mountain has numerous fresh erratics and shows clearly the features of glacial erosion. The region was most certainly completely overridden by ice.

TABLE MOUNTAIN, BONNE BAY

South of Bonne Bay another of the west coast ultrabasic intrusive massifs stands as a flat-topped, steep-sided mountain rising to over 2300 feet above sea level. Its top, barren of vegetation because of the toxic effect of the bedrock, is covered by a great felsenmeer (Pl. 2, fig. 2). The angular blocks of serpentine range from several inches to several feet, a foot or 2 being the most common. Roches moutonnées were seen in various stages of destruction by frost splitting. In several cases it was seen, by their sizes and shapes, that blocks up to a ton or more had been split off and moved 2, 3, to 10 feet from a parent ice-rounded ledge of bedrock (Pl. 2, fig. 2). Among the angular blocks of the felsenmeer about 200 rounded erratics of quartzite and 20 or more of pink and gray granite were found during a 2-hour search (Pl. 2, fig. 3). They were well down among and below the felsenmeer blocks. Where it was possible to get down to the "ground" between the blocks a little digging usually revealed erratic pebbles in till. It appears from these observations that the surface was originally gently rolling and till-covered except where scattered ice-rounded ledges projected. The felsenmeer was formed from these latter by frost splitting and was spread by heaving and solifluction over the surface in late glacial and postglacial time. The granitic erratics are all hard and firm indicating a Wisconsin age. A 3-inch flat pebble of slate was found with fresh, clear, and well-formed striae on both its sides. This pebble alone would be convincing to most glacialists of the recentness of the glaciation.

Two cirques each about half a mile by a mile notch the north scarp of the Table Mountain and debouch with local looped moraines on the valley level at 500 to 522 feet at the base of the escarpment (Pl. 1, fig. 3). The floor of a smaller cirque is at about 1100 feet. Perennial snow lies against the headwalls of these cirques, and obviously during late glacial time they were occupied by valley glaciers after the overriding ice had dwindled.

GROS MORNE, BONNE BAY

Bad weather prevented any study of the top of this flat-topped mountain at 2651 feet (Pl. 1, fig. 2), but later in the summer Flint and his party made the ascent and assured the writers that the top had been overrun by Wisconsin ice. Dennis, Woodruff, and Steers, of the Geodetic Service of Canada, who were engaged in the primary triangulation of Newfoundland, at the writers' instigation and under their instructions, went to considerable trouble to collect carefully and submit samples of erratic stones from the tops of several other mountains in the vicinity of Bonne Bay and farther north. In every case these stones were fresh and doubtless were transported during the Wisconsin stage.

LONG RANGE, EAST OF PARSONS POND

Dr. Helgi Johnson, of the Newfoundland Geological Survey, reports fresh erratics, rounded glacial forms, ponds, and insequent drainage on the top of the Long Range Plateau east of Parsons Pond. Fresh erratics from a triangulation station on the summit of the Plateau (2198 feet) were received from Mr. Steers.

LONG RANGE BETWEEN HAWKE BAY AND GREAT HARBOR DEEP

In his traverse across the Long Range from Hawke Bay to Great Harbor Deep, Foley (1937, p. 4) describes erratics and other glacial features on the uplands. In 1937 he accepted Coleman's interpretation that they were the product of Kansan glaciation but he has since indicated that what he had seen were no more weathered than are those from Table Mountain and MainTopsail collected by the writers.

TOPSAILS

Main Topsail (1822 feet) is a striking little monadnock which rises sharply 250 to 275 feet above the surface of the High Central Plateau of central Newfoundland. Its summit is about 100 feet wide and 400 to 500 feet long. Its southeastern end is gently rounded, whereas its northwestern end is a shallow saucerlike depression in which water stands after a rain. At the time of the visit two shallow pools of water were observed. The hill itself is composed of gray granite, but boulders and cobbles of pink granite, diorite, basalt, and a vesicular dark lava are scattered about on the summit (Pl. 2, fig. 1). All the erratics are either fresh and firm or only slightly crumbly at the surface due to frost splitting. Arkosic sand is as abundant as on most granitic mountains where frost splitting is the dominant type of weathering. This same type of arkosic sand is abundant on the heavily glaciated surface of the surrounding plateau which is also underlain by granite.

The Gaff Topsail also is granite and is rounded by glaciation and littered with fresh erratics composed of diorite, basalt, felsite porphyry, and two kinds of granite.

HARPOON HILL, RED INDIAN LAKE

This monadnock, one of the many in this area, rises sharply about 500 feet above the very gently rolling surrounding surface. It is composed of basic rock. On its rounded summit a 10-minute search produced rounded pebbles, cobbles, and boulders of chert, basalt, gray granite, pink granite, and vesicular felsite. There can be no doubt that this area, including the tops of the highest hills, was overrun by Wisconsin ice.

Local men report that the top of Skull Hill, another conspicuous monadnock near Millertown Junction, is strewn with rounded boulders.

ANNIEOPSQUOTCH MOUNTAINS

J. E. Quigley (1935, p. 20) found a glacially grooved surface on top of the Annieopsquotch Mountains at an elevation of slightly over 2000 feet.

> "On the very tip of the northern peak of the mountain is a low rounded knob about 20 feet broad and 10 feet high. Its surface is sharply cut by east-west grooves about three inches deep and eight inches wide to make it look like a large pecten shell. No striae remain because weathering has disrupted the grains of feldspar of the gabbro thus pitting the surface. The rock surface is otherwise hard and strong and not at all disintegrated. Since the knob is the highest peak of the range it is very doubtful that moss or gravel could have covered and protected it for any length of time."

The evidence here is convincing that Wisconsin ice overtopped and grooved this, the highest mountain mass of the south-central part of Newfoundland.

WHITE BAY

The summits of the uplands on both sides of White Bay near its head show by abundance of erratics, ice-carved rock surfaces, abundance of lakelets, U-shaped valleys, and patches of drift that no parts have escaped Wisconsin glaciation.

BAIE VERTE

Baie Verte is a deep fiord on the north coast on the peninsula between White Bay and Notre Dame Bay. The summits of every hill climbed bear abundant evidence of recent glaciation.

NOTRE DAME BAY

Most of the shores and many of the islands of Notre Dame Bay have been studied, and without exception all bear clear and convincing evidence of recent glaciation. Erratics are fresh, glacially eroded surfaces have been little effaced, and there has been little stream erosion since the disappearance of the ice.

FIGURE 1. FOSSILIFEROUS DELTA DEPOSITS ON KAME OF THE ST. GEORGES RIVER DRIFT

FIGURE 2. PEBBLY DELTA SANDS ON LAMINATED MARINE SILT

FIGURE 3. DELTA AT PORT AU PORT

BAY ST. GEORGE DELTA

FIGURE 1. TILL OF THE ST. GEORGES RIVER DRIFT NEAR IRISHMANS BROOK
Photograph by W. S. Bryan.

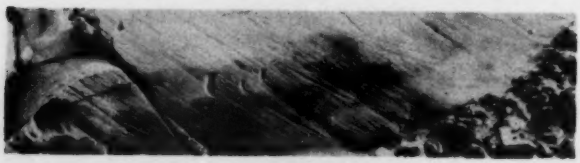

FIGURE 2. CRESCENTIC GOUGES PORT AU PORT
Photograph looking west-southwest.

FIGURE 3. CRESCENTIC GOUGES AGUATHUNA
Pencil points N. 30° W.

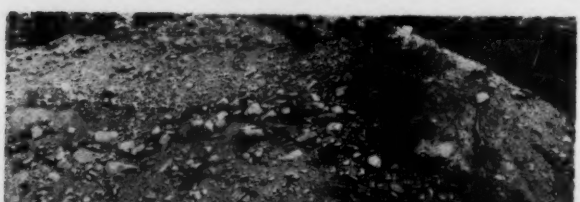

FIGURE 4. KAME 4 MILES EAST OF BADGER

DRIFT, STRIAE, AND GOUGES

RED CLIFF, NEAR GRAND FALLS

This hill (560 feet high), an outlier of the 700- to 800-foot upland farther northwest, has a glaciated summit, and the same seems to be the case for the hills to the northwest.

EASTERN NEWFOUNDLAND

The upland surfaces from Notre Dame Bay to St. John's bear abundant evidence of glaciation so recent that subsequent stream erosion has hardly made an impression.

GLACIAL STRATIGRAPHY OF BAY ST. GEORGE AREA

GENERAL CONSIDERATIONS

This area was chosen, upon the advice of Doctor Snelgrove, for fairly detailed investigation of the drift phenomena because: (1) The drift was known to be relatively thick, (2) coastal erosion had produced exposures, and (3) it is fairly accessible. The bay has a shore line of about 40 miles from Port au Port peninsula at the northwest to the Anguille Mountains at the south. It is flanked by the West Coast Lowland except where the narrow Indian Head Range, between Stephenville and Stephenville Crossing, rises to 600 to 700 feet. The lowland is mantled with drift into which the waves have cut a sea cliff 80 to 100 feet high, thus laying bare an exposure comparable to that of the coast of Norfolk in England.

In brief, three episodes of glaciation are recorded along the shores of the bay, in order of age: (1) the St. Georges River Drift, (2) Bay St. George Delta, (3) Robinsons Head Drift. The St. Georges River Drift is a lower suite of drift deposits consisting of till, plain gravel, and kame gravel. The Bay St. George Delta is an intermediate suite of glacio-marine deposits consisting of locally fossiliferous silt and silty clay and bottom-set, fore-set, and top-set delta deposits. The Robinsons Head Drift is an upper suite of glacial deposits again consisting of till, plain gravel, and kame gravel.

A diagrammatic cross section as revealed in a traverse of the coast line from Port au Port to the Anguille Mountains is shown in Figure 1. Slumping has in places concealed the materials, but on the whole waves and currents have kept the section remarkably well exposed for mile after mile.

COASTAL EXPOSURES FROM PORT AU PORT TO ANGUILLE MOUNTAINS

The village of Port au Port stands on a pitted sand and gravel delta whose top is now 100 to 110 feet above sea level (Pl. 3, fig. 3). A good exposure near its west end, along the south shore of Port au Port Bay, shows fore-set bedding 75 feet in amplitude dipping at an angle of 20°–30° in the direction N. 70° W. On the Bay St. George shore, one mile east of the end of the delta, 18 feet of red-brown, calcareous

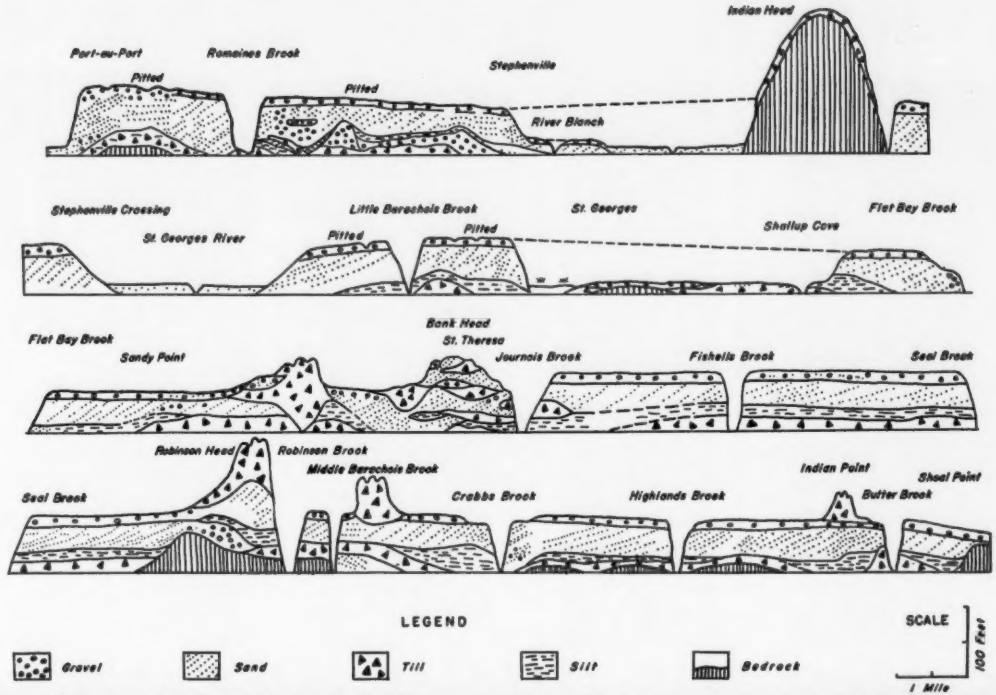

FIGURE 1.—*Diagrammatic section of drift along coast from Port au Port to the Anguille Mountains*

compact till underlies the delta fore-set beds. The till is studded with a great variety of rocks—granite, diorite, basalt, rhyolite, gneiss, schist, limestone, sandstone, and shale. The sedimentary material can well be of local derivation—limestone from the underlying Ordovician and sandstone and shale from the adjacent Carboniferous Codroy and Barachois rocks. The red brown color of the till is obviously derived from these latter red brown rocks of the West Coast Lowland. One mile east, the top of the till gradually descends below sea level. The character

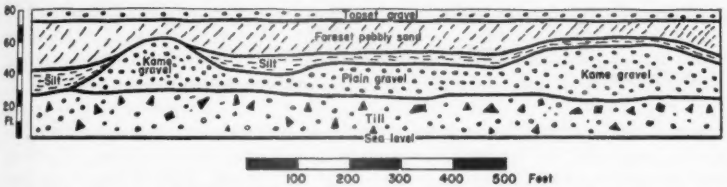

FIGURE 2.—*Bay St. George Delta (silt, fore-set sands, top-set gravel) lying on St. Georges River Drift (till, kame gravel, and plain gravel)*
Two miles west of Stephenville.

also changes to a drab gray noncalcareous till, evidently derived from crystalline areas of the interior of Newfoundland. This alternation, intergrading, and intermixing of gray and brown material of the St. Georges River Drift is characteristic of the exposures all around the bay.

The till rises above sea level at Romaines Brook and is thence visible intermittently to Stephenville. Above the till lies the coarse outwash gravel of the St. Georges River Drift. In places it shows the horizontal stratification of plain gravel, at others the steeply inclined, disturbed, and irregular bedding of kame gravel.

Lying upon the St. Georges River Drift is the Delta series, consisting of fine dense silt, locally known as "pug" (Pl. 3, fig. 2). In places this silt lies on till, elsewhere on the plain gravel, and in three places between Romaines Brook and Stephenville is seen to drape over kames (Fig. 2). The "pug" grades upward into fore-set pebbly sand dipping uniformly westward. The top of the bluff in most places is underlain by 8 to 10 feet of coarser top-set gravel. As the pits of the delta become more numerous and larger the coastal exposures are limited to flat-topped hills separated by lowlands (pits) now modified by postglacial fluvial erosion. In the exposure one mile west of Stephenville highly fossiliferous sand and "pug" drape over an 18-foot kame of St. Georges River Drift (Pl. 3, fig. 1). The highest fossils are, by hand level, 35 feet above the high-tide strand line.

In the immediate vicinity of Stephenville the pitted delta surface has been reduced by River Blanche and its tributaries to strath valleys with broad low terraces. The same is true in the vicinity of Stephenville Crossing where Harry's Brook has partly degraded the delta surface to fluvial terraces.

The delta is absent at St. Georges River which was evidently the site of an open body of water during delta-building time, for its south side at the western end is composed of bottom-sets rising to fore-set structures dipping northward—*i.e.*, toward St. Georges River. Several hills of the St. Georges River Drift project above the delta. The one at Mathes Point is terraced as by marine planation during shore stillstands of a progressively rising land. The terraces were estimated to be

about 50, 65, and 85 feet above present sea level. These terraces pass around the west end of the hill and become indistinct on the gently sloping distal surface of the delta deposits toward the west-southwest.

From St. Georges River to the village of St. Georges, coastal exposures show till overlain by "pug" and fore-sets dipping continuously northward and northwest-

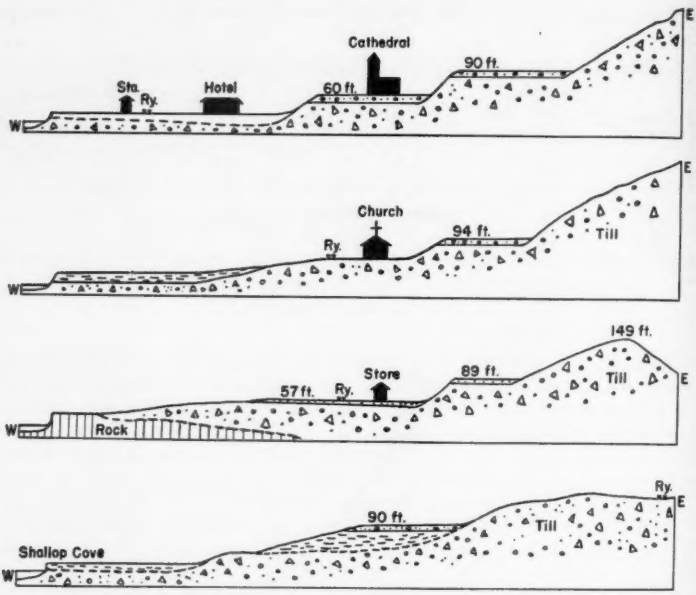

FIGURE 3.—*Sections of the St. Georges lowland, spaced about one mile apart*

The upper section is at the north end and the lower one at the south. Symbols same as in Figure 1.

ward. The fact that the fore-sets dip the same way on the two sides of the Little Barachois River suggest that this river has cut its valley through the delta. The delta surface is marked by small pits as well as large ones such as that followed by the middle course of this river and another followed by the railroad to the south of the river. These depressions therefore are large ice-block depressions breached at their seaward ends by the present drainage.

The village of St. Georges occupies a lowland between fingers of the delta. The lowland extends about 4 miles along the coast and is half a mile to a mile wide. It is flanked on the landward side by 300 foot-hills of St. Georges River Drift notched to fairly continuous terraces at 60 and 90 feet above sea level (Fig. 3). The northeast end of the lowland is faced by fore-set delta beds dipping southwest, whereas similar beds at the southeast end of Shallop Cove dip northeast. The lowland is underlain by till, water-washed sand, and gravel, and not uncommonly by "pug." The well at the hotel passed through 4 feet of black peat, 4 feet of gray silt, 12 feet of red silt, and 3 feet of gray sand with a marine shell in it.

Many boulders litter the surface. These boulders seem best explained as having been washed out of the till during a former high stand of the sea. Soil creep and solifluction may likewise have played a part in their present distribution. Considerable trouble has been encountered in soil creep on the scarps of the terraces. The foundation of the courthouse and the cathedral wall have both cracked and slumped. Peat has accumulated to considerable thickness in parts of the lowland, as at the railroad station and at Turf Point.

The delta surface rises to 57 feet on the south side of Shallop Cove. The seaward bluff exposes 25 feet of gray fossiliferous "pug," grading upward into fore-set sands surmounted by 5 feet of top-set gravel. From here to Flat Bay Brook and thence southwest for about 3 miles the surface of the delta is terraced with fluvial scarps 10 to 20 feet high, showing that this section of the delta has a fluvially cut surface degraded from some higher level.

One and one-half miles west of the junction of Sandy Point with the mainland an 88-foot bluff exposes from the bottom upward red silt 10 feet, gray silt 10 feet, gray sand 20 feet, gray till 35 feet, coarse sand, gravel, and boulders 13 feet. The gray silt contains fossils at the western end of the exposure. The relationship shows readvance of glacial ice after deposition of the delta beds. At Bank Head (St. Teresa Head) till also lies above delta beds.

During the next mile to the southwest exposures show in succession:

	Gravel	Till
Sand	Sand	Sand and silt
Silt	Till	Till
Till	Silt	Silt
Sea level	Sea level	Sea level

On the west bluff of Journois Brook the 85-foot exposure shows:

Gravel, 1- to 2-inch pebbles
Sand, horizontal stratification
Till, pinkish
Silt, gray

The very intimate association here of till and silt suggests further that the later glacial invasion projected into sea water.

From Journois Brook to Robinsons Head is seen the simple delta succession of till at base, then "pug," then north-dipping fore-set sands, and some top-set gravel at the top. The upper drift again appears at Robinsons Head in seaward exposure of something over 200 feet. Furthermore, the topography of this headland is that of hummocky terminal moraine. Likewise 2 miles farther southwest along the coast the upper till and morainal topography is exposed in the coastal section. The most southerly exposure of the super-delta drift is seen half a mile northeast of Harbor Point. The gray noncalcareous upper drift is evidently composed largely of material from the crystalline rocks of the Long Range. Since valley glaciers in that latter region would have been too small to have reached to Robinson Head, it is inferred that the deposition here was marginal to a stand of the inland ice cap.

Two and a half miles west of Robinsons Brook 35 feet of dense, red brown, fossiliferous "pug" underlies 30 feet of north-dipping fore-set sands. Fossils were also found in 25 feet of "pug" near Highland Brook and on the west side of Harbor Point, and in "pug" on top of 40 feet of till on the east side of Butter Brook.

AREAL DISTRIBUTION

St. Georges River Drift.—This drift occurs at the surface in only seven recognizable patches (Fig. 4). There is an indistinct area on the lower flanks of Table Mountain at Port au Port. A patch of unknown ex-

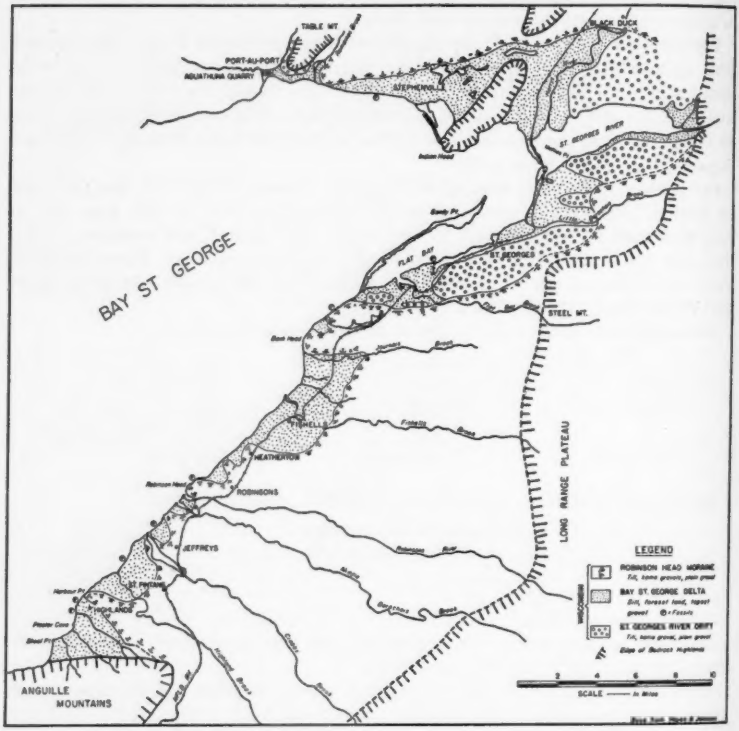

FIGURE 4.—*Map of Pleistocene formations of the Bay St. George Area*

tent lies on the north shore of St. Georges River. A third flanks the south shore of the same river and forms the headland at Mathes Point. A fourth and smaller area forms the upland one mile north of the middle part of Little Barachois Brook. A fairly large area lies to the southeast of St. Georges and, as said before, forms the hills southeast of the town. Two other small patches lie southwest of Flat Bay Brook.

Bay St. George Delta.—This delta fringes the coast from Port au Port to the Anguille Mountains. It is interrupted by the Indian Head

Mountains and is concealed below Robinsons Head Drift at the five places where this later drift spreads out to the shoreline.

Robinsons Head Drift.—The moraine of this drift is easily traced as a hummocky belt of bouldery drift from Romaines Brook, where it comes out to the coast, swinging northeastward to the north of Stephenville, across the Indian Head Range at Long Lake, and thence to Harrys Brook at Black Duck. It was not traced east of here, but the view from the train window and also from the air suggests that it probably swings on eastward to the foot of the Long Range in the neighborhood of St. Georges River.

The moraine was again encountered 2 miles southeast of St. Georges whence it passes southwestward across Flat Bay Brook and out to the sea 3 miles north of Bank Head. The moraine from here to the Anguille Mountains swings in and out in the lobate design of the margin of an ice sheet.

BAIE VERTE

A brook flowing into the head of Baie Verte exposes 22 feet of till and marine clay. The base of the deposits is 60 feet above sea level. Three feet of till is overlain by 6 feet of fossiliferous marine clay. This clay is succeeded by more till, and this in turn by outwash. There evidently was a time of ice advance followed by retreat during which the fossiliferous marine clays were deposited when sea level was at least 70 feet higher than at present. Ice again advanced to deposit the upper till. The history on Baie Verte is thus parallel to that of Bay St. George.

DRIFT IN OTHER PARTS OF NEWFOUNDLAND

TILL

Topsails.—At Gaff-Topsail station, 4 feet of red-brown drift is exposed along the railroad. The pebbles, boulders, and angular blocks in the drift are all fresh and firm indicating a Wisconsin age. The brown color is due to iron stain imparted by post-Wisconsin podsolization. The same red-brown stain is seen on the sides and bottoms of most of the surface boulders in the neighborhood. The surface is abundantly strewn with small to very large erratics.

Buchans.—Mine workings show that there is up to 157 feet of drift, largely composed of massive brownish to grayish dense till studded with local stones up to 8- and 10-foot boulders, with considerable embedded outwash of sand, silt, and gravel. Deposits are noncalcareous. The weathering is again typically post-Wisconsin.

Kittys Brook.—From Kittys Brook Station to the top of the Plateau at Gaff Topsail the railroad winds in and out among morainal hills 50 to 200 feet high composed of gravel and till. Interspersed are kettle holes of equivalent dimensions, many of which contain lakes. As seen from the slow-moving train, the morainic material is granitic, as would be expected with ice advancing from the granitic plateau.

Hinds Brook.—Southeast of Howley, Hinds Brook also contains a large terminal moraine equivalent in dimensions and roughness to the one in Kittys Brook Valley. It is likewise composed mainly of igneous materials, but there are some metamorphic rocks present.

The Kittys Brook and Hinds Brook moraines were built when tongues of the upland ice cap projected part way down the valleys. Outwash deposits of the Howley area, splendidly exposed in the village, may well have been formed during this phase of the deglaciation. The ice must have remained for a considerable time in this position to have produced moraines of such magnitude. This stand is therefore considered to have been one of the major episodes of the deglaciation. It was either a halt in recession or possibly a readvance.

Badger and Gull Pond.—The elongate northeast-southwest hill south of Badger is 200 feet wide and rises 45 feet above the flat plain of the Exploits River. It is composed of fairly coarse gravel with a few scattered boulders lying on top. From its shape and composition it is thought to be an esker.

The highway east of Badger cuts through thin gray silty till and low kames of cobbly and bouldery gravel (Pl. 4, fig. 4). Argillite, quartzite, and diorite pebbles predominate, but gray and pink granites were also found. Oxidation of the drift ranges from 1-4 feet deep. The freshness of the drift suggests a Wisconsin age.

At Gull Pond, 20 miles north of Badger, the country has been heavily glaciated. Huge boulders were transported several miles to the northeast, as indicated by many boulders of copper ore in the drift which are identical mineralogically with the ore which outcrops near the western end of Gull Pond. Some of the boulders measure 10 by 15 by 8 feet. It is reported that a prospector, thinking one of the boulders was an outcrop, started to sink a shaft in it.

Searston.—Near the mouth of the Codroy River a mile-long section of till on bedrock is exposed by wave erosion along the southwest coast between Searston and Larkin Point. Fifty feet of gray calcareous till is seen 2½ miles south of Searston. It is leached to a depth of 3½ feet and oxidized a reddish-brown to a depth of 6 to 6½ feet. This is the

amount of weathering expected in Wisconsin till. Granite, diorite, porphyry, basalt, gneiss, sandstone, shale, limestone, (some with crinoid stems), and dense white dolomite are present. The dolomite suggests a source from the Port au Port region, and the gray color suggests an origin other than from the red-brown Barachois series immediately to the east which stains the till of the Codroy Valley brown. The Anguille Mountains just to the north are partly composed of limestones but not dolomite. Three miles south of Searston the following section is exposed:

Till, oxidized yellowish, 15 feet.

Sand and gravel, oxidized, calcareous, 5 to 8 feet.

Till, gray, calcareous, 30 feet.

The greater depth of oxidization in the upper till is due to the better drainage produced by the underlying sand and gravel layer.

Sandy Lake.—Extensive morainal deposits extend from the head of Sandy Lake in the Grand Lake-White Bay Basin nearly to the head of White Bay. The thickness is not known, but some of the morainal hills are 100 feet or more above the adjacent low places. It is thought that the ice moved north from the interior of Newfoundland through this basin into White Bay and the Atlantic Ocean.

St. John's.—Numerous excavations about St. John's expose till, particularly along the side of the hill south of the railroad. The till is surprisingly fresh, and erratics seem to be largely of local origin. No granite erratics were seen, and none from any known rocks of the High Central Plateau. As in most places, there is a podsolized zone at the top below which is a zone in which ferric hydroxide has been concentrated.

Placentia Junction to Argentia (Placentia Bay).—Small railroad cuts over an extensive plain, ranging in elevation from 400 to 450 feet, show fresh till. At Argentia 25 feet of fresh till is exposed, and this thickness seems to be normal for an extensive area. Erratics seem to be largely sedimentary except a few basic crystallines. No granites were seen. Striae near Argentia trend northeast and southwest.

Brigus Junction.—There are excellent exposures of till about the station, along the railroad both east and west, and on the branch road to Carbonear. There are some well-formed morainal hills on the road to Carbonear. No boulders of igneous rocks were seen in place in till.

The apparent absence of granites of High Central Plateau derivation lends weight to the suggestion that the Avalon Peninsula had its separate ice cap during the waning phases of glaciation. This suggests that, if ice from the High Central Plateau had once overrun the Avalon Peninsula and had deposited erratics of High Central Plateau origin, the

radiation from this local ice cap would have moved them beyond the limits of the present shores and left erratics of local derivation in place.

Terra Nova.—Near Terra Nova at an elevation of 400 to 500 feet are extensive deposits of glacial forms up to 30 feet in height. Granite erratics are abundant. The hills are considered to be mostly crevasse fillings.

Notre Dame Junction.—Between Terra Nova and Notre Dame Junction there are numerous exposures of fresh till. Detailed description of each exposure is unnecessary, but one of these deposits should be described as it was specifically mentioned by Coleman (1926, p. 204). This is the exposure at Notre Dame Junction where about 6 feet of till is exposed. The till in the neighborhood seems generally thin as numerous low rounded knobs of unweathered bedrock project at the surface. The erratics in the upper part of the till are fresh, though stained with ferric hydroxide during podsolization. This is underlain by gray till with fresh erratics. Coleman seems to have interpreted the red-brown color as a measure of long weathering of the zone in which the ferric hydroxide is present.

DELTAS

Humber.—Besides the almost universal mantle of drift, several delta deposits were studied by the writers. One of these lies just east of Humbermouth. It is half a mile long by a quarter of a mile wide, and its top is 150 feet (Paulin) above sea level. Excavation for railroad ballast has exposed westward-dipping delta fore-set bedding at least 100 feet in amplitude. At the base of the west end of the cut red-brown silt is exposed. The other mass of delta material is at 157 feet above sea level—(Paulin) against the hillside south of West Corner Brook. The 38-foot terrace on which the ball park stands exhibits two distinct stream-cut scarps on its surface and evidently represents an erosional level graded to some unknown stand of the sea. The underlying red-brown "pug" is fossiliferous. The other terrace surfaces of Corner Brook are of the same fluvial nature.

Coleman (1926, p. 213) reported marine fossils between till at an elevation of 140 feet in the town of Curling. He considered them to be of interglacial age. It seems unlikely that a deposit of unconsolidated material, such as the marine deposits are, lying on the relatively steep side of a deeply and severely glaciated fiord, such as the Humber is, would survive the intense glaciation of Wisconsin time. The interpretation reached in the present study is that the marine deposits are late glacial and correlated with the Bay St. George episode of Wisconsin glaciation.

Bonne Bay.—Just south of Woody Point on the South Arm of Bonne Bay the waves have exposed the fore-set beds of a delta whose top is between 165 and 180 feet (Paulin) above sea level. It was evidently built out into the waters of the bay after ice had abandoned it but before the land had risen to its present position. Upland glaciers were probably present, however, to supply the large amount of coarse material seen in the top-set beds.

Springdale, Halls Bay.—The village stands on a 30-foot terrace at the foot of an extensive deltaic deposit of sand and gravel with scattered boulders strewn upon the top. Boulders greater than 6 inches in diameter seem to comprise a minor part of the deposit. It is at least 1500 feet long, 800 to 900 feet wide, and averages 200 feet in thickness. It rests directly against the bedrock hill back of Springdale. The top is 260 feet above sea level. The upper surface is somewhat hummocky and pitted. A gully in the lower terrace reveals fossils in "pug" up to 27 feet above sea level. This deposit is an eroded remnant of a once extensive deposit of much pitted outwash deltaic gravel that once filled all the valleys that drain into Halls Bay. Extensive "let down" or "collapsed" topography attests to the presence of numerous large ice blocks during the deposition of the outwash. All these deposits have a wave-cut terrace on the sides next to Halls Bay. At Springdale this terrace is 30 feet above sea level on the seaward, or outer, side and 55 feet above sea level back of the houses.

Another fragment of this delta deposit is present adjacent to South Brook on the southeast side of Halls Bay. Three terraces are shown in this deposit. The lowest is 15 feet above sea level, the second terrace is 55 feet high on the seaward edge and 65 feet high on the inner edge (about 150 yards wide where measured). The third terrace is the summit of the deposit at 240 feet above sea level. Terraces 1 and 2 are wave cut, terrace 3, the highest, is constructional and was made by meltwater from glaciers that drained into Halls Bay from the interior of Newfoundland. The summit was graded to the sea level of the time.

Botwood.—Botwood is situated between Peters Arm and Northern Arm of the Bay of Exploits. In the valley that drains into Peters Arm are two hills of which the summits are judged to be about 250 feet high. One of these is conspicuously isolated in the bottom of the valley. Both seem to be entirely composed of gravel, and each is a remnant of a gravel deposit that once entirely filled the valley to a height of about 250 feet. These deposits were graded to sea level of the time, and the summit of each may be correlated with the summits of the extensive deposits on Halls Bay.

Eastern Newfoundland.—Outwash delta and fan deposits are abundant in eastern Newfoundland. Nice exposures are in the railroad between Avondale and Kellygrew, at Shoal Harbour, on Shoal Harbour Brook, at Gambo, and numerous other places.

Norris Arm.—About 3 miles east of Norris Arm a large exposure of delta gravels and sands are being worked by the Newfoundland Railway. There is a 500- to 1000-foot face with a height of 15 to 20 feet. The inclined stratification has a strong northerly component but a westerly component on the west end and an easterly component on the east end, thus indicating that the ice lay to the south. Marine fossils have been reported from this deposit whose summit is over 100 feet above sea level. It was probably graded to sea level at the time of its deposition.

HISTORY OF WISCONSIN GLACIATION

LABRADORIAN GLACIATION

Flint (1939, p. 1909) proposes that the progressive rise toward the northwest of the wave-cut benches in western Newfoundland means that it partook of Labrador depression by a Labradorian ice cap. Confirmatory evidence, based on the transportation of drift boulders, will have to await a much fuller knowledge of the bedrock of both places. Striae in most places indicate ice radiating outward from Newfoundland. On the Port au Port Peninsula, however, evidence described later suggests that ice moved southward during one episode and westward at a slightly later time. The concept of glaciation by ice from the Labrador center and the evidence, from striae, of glaciation by an independent ice cap may be brought into harmony by assuming that glaciation from Labrador took place at the climax of the Wisconsin stage, when ice may well have passed not only over Newfoundland but out to deposit the well-known drift of the Grand Banks. This was the time of the low sea level of the Wisconsin maximum. As the Labradorian glacier waned part of it may have persisted on Newfoundland, acquired radial motion as impeding ice melted away from its margins, and thus become a local ice cap whose movement would have largely obliterated any earlier striae. The highlands of the Long Range Plateau and High Central Plateau would have supplied gathering grounds for the maintenance of such an ice cap. Be these deductions as they may, the known glacial history of Newfoundland begins with an ice cap completely covering the island and radiating outward with its outer limits beyond the present shores.

STAGES OF THE NEWFOUNDLAND ICE CAP

St. Georges River Drift stage.—From the evidence of striae (Fig. 5) as now known, ice spread outward from the island in all directions. The local

topography of course influenced the motion of the basal part of the ice and caused it to follow valleys. Striae on the sides of the larger fiords such as the Humber and Bonne Bay parallel the valleys. Ice seems to

FIGURE 5.—*Striae of Newfoundland*

Compiled from published sources, from observations of the authors, from unpublished records of the Newfoundland Geological Survey, and from unpublished maps of Hans Lundberg. The suggested centers of late glaciation are from Lundberg. Center I is thought to have antedated center II.

have drained off the uplands into the valleys and thence out to sea. In the process the main valleys were deepened into the fiords as we now see them.

Southwest-trending striae at Placentia on the southwest side of the Avalon Peninsula show that at some stage ice radiated outward from this peninsula in all directions (Chamberlin, 1895, p. 467; Coleman, 1926, p.

200). Likewise striae on the southeast side of Hare Bay "Serpentine" Hills suggest ice radiating from it.

Complicated crossing sets of striae are preserved on the dense limestone below till at Port au Port on the north shore of Bay St. George. The bearings of striae on successive ledges are as follows: (1) N. 10° E., N. 40° W., N. 5° E.; (2) N. 20° W., N.-S., N. 5° E., N. 20° E.; (3) N. 70° W., N. 40° E.; (4) N. 10° E., N. 10° W., N. 40° W., N. 50° W., N. 85° W., N. 60° E.

Where it was possible to see the shape of the striae they were normally blunt at the western or southern end. The horns of the many 2-inch crescentic gouges point northward or northwestward (Pl. 4, fig. 2). Where striae crossed each other the set parallel with the shore is younger than that at a considerable angle to it. It is thus concluded that ice entered Bay St. George from the north and that later ice came down Bay St. George, at times the lobe spreading outward across the site of the present shore line and other times moving parallel with it.

On the south shore of Port au Port Peninsula, half a mile southwest of "The Gravels" on the tombolo, 10 feet of brownish-drab calcareous till lies on dense limestone and below 60 feet of sand and gravel. The limestone is striated by two sets of scratches—one N. 22° E., parallel to the shore here, and the other N. 40-50° W. The vertical faces of limestone ledges are striated and rounded by ice moving parallel to the shore. Striae on the next ledge west bear N. 20° E. and N. 30° W. Striae on a limestone ledge 2 miles southwest of the tombolo are north-south and accompanied by crescentic gouges with the horns pointing northward. These markings are about 2 inches across and scattered rather than in rows like chatter marks. Gilbert (1906, p. 303) concluded that this kind of mark was made by ice coming from the direction in which the horns point, in this case from the north.

On the north shore of Port au Port Peninsula three-fourths of a mile west of Aguathuna, striae bear N. 10° E., and N. 64° W., the latter being younger. At the quarry itself stripping has exposed striae in several places. At the top of the quarry clear-cut unweathered striae bear N. 10° W., N. 10° E., N. 30° E. Several 2- or 3-inch east-west depressions or little "valleys" in the surface of the limestone are significant for the north sides are sharp and plucked whereas the south sides are normally smoothed, rounded, and striated showing ice movement from north to south. In the eastern part of the quarry a large newly stripped surface of dense homogeneous limestone dipping 20 degrees northward shows striae N. 20° W. to N. 20° E. There are also perhaps 40 crescentic gouges on the exposed surface, all with the horns pointing northward (Pl. 4, fig. 3). The blunt ends of striae, where they could be seen to end, are at the south.

From these various striae and glacial markings it is deduced that glacial ice first crossed the Port au Port area from the north and later came from the east. This succession of events would fit well within the proposal made earlier that Newfoundland was at first affected by ice from Labrador and later had its own outward-radiating ice cap. The ice which moved southward may have been either Labrador ice or Newfoundland ice which, farther north, moved out into the St. Lawrence Gulf, there encountered south-moving Labrador ice, and was pushed southward by it. This kind of movement is believed to have happened in England, where Scottish ice is thought to have moved eastward, encountered Scandinavian ice in the North Sea, and been bent southward and southwestward into Norfolk in order to bring the Scottish erratics to the latter place. Mr. A. House of Aguathuna quarry reports several labradorite boulders. However, since similar rock outcrops on Indian Head, this bit of evidence is not conclusive as to the presence of Labradorian ice.

During the episode of maximum extension of the Newfoundland ice cap as well as during the waning stages of this episode, the St. Georges River Drift sheet was deposited. It is not known whether ice at this time was in contact with sea water, though intimate relations of till to "pug" 2 miles south of St. Georges suggest it, but marine waters invaded the present land area during the waning of this ice. Innumerable large and small pits and collapsed or let-down topography of the delta attest to ice blocks surrounded or buried by marine deposits. It is thought likely that sea level rose to approximately its present height immediately following this episode.

Bay St. George Delta stage.—After ice had waned well within the limits of the present shore line in the Bay St. George area and out of the fiords farther north the extensive delta of the former area and the numerous smaller ones of the latter were deposited. Dr. H. G. Richards, to whom the fossils were submitted, reports that the fauna near Stephensville is from shallow water of slightly less than normal ocean salinity, but of temperature about the same as the waters there today. The fauna collected near Crabbs Brook shows brackish conditions similar to those in the Champlain Sea of Pleistocene time. The abundance of sand and gravel to build the deltas also suggests the presence of melting glacial ice not far distant.

Robinsons Head Drift stage.—Readvance of the ice cap over the delta beds resulted in the deposition of the Robinsons Head Drift and moraine. The intimate relationship, in some of the coastal exposures, between till of this drift and marine deposits suggests that the ice advanced into shallow sea water.

Kittys Brook moraine stage.—During the general waning of the ice cap of the central plateau it reached a stage when ice tongues pushed only part way down the valleys trenching its western escarpment. These tongues, however, persisted long enough in this position to deposit massive terminal moraines and thus mark one of the major recessional stages of the ice cap history.

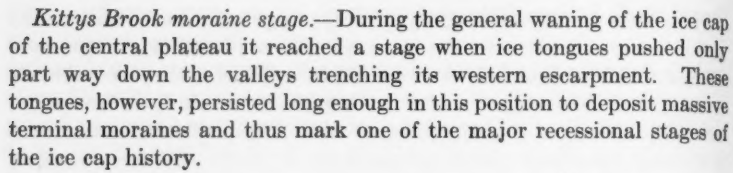

FIGURE 6.—*Plucking of Main Topsail*

The oversteepened sides of the Topsails and other monadnocks on the High Central Plateau call for a special explanation, for normal overriding by an ice cap would probably have rounded and softened preexisting hills unless these were situated near the center of radial movement. It is suggested that, as the ice cap on the plateau thinned, the tops of the Topsails were the first to emerge above the ice. Plucking by outward-moving ice lying against their flanks then became especially effective and oversteepened their sides (Fig. 6). Plucking however would have been effective on leeward sides at all times. Such oversteepened monadnocks as Skull Hungry and Harpoon Hills were probably oversteepened while under ice.

LOCAL VALLEY GLACIATION

The ice cap finally disappeared and only local glaciers remained in valleys on the steep sides of the uplands. These local glaciers etched out cirques at the heads of these short valleys and in favorable places deposited small looped moraines at their lower ends. Examples are seen in McIsaac and Stephens Brooks at South Branch, in the valley southeast of Saddle Mountain near Tompkins, on the north slope of Table Mountain at Bonne Bay, and elsewhere. In many of these cirques perennial snow and ice still persist.

LATE GLACIAL AND POSTGLACIAL UPLIFT AND DISSECTION

Wave-cut terraces as well as marine sediments above present sea level attest to postglacial uplift. Others (Daly, 1921; Flint, 1939) have described the evidence of uplift in detail. The fluvial terraces of the streams in the Bay St. George area may well have been graded to the intermittently falling sea level as the land rose.

WEATHERING OF THE DRIFT

It has been stated that the till and erratics show evidence of great age and should thus be correlated with the Kansan. The writers cannot subscribe to this view. Erratics everywhere are remarkably fresh and show little or no evidence of chemical weathering. Frost breaking is about the only weathering phenomenon apparent. Potentially millions of undecayed erratics were observed, and less than a dozen decayed individuals were found, although search was made for them. This condition of erratics should be contrasted with the Wisconsin drift in the upper Mississippi valley, where thousands of decayed erratics may be collected in almost any exposure.

The writers are of the opinion that the view of great weathering probably is founded on misinterpretation of the concentration of ferric hydroxide below the surficial zones of weathering. However, neither in the podsolized zone nor in the iron-stained zone beneath are the erratics decayed.

SUMMARY OF RESULTS

The results of the study may be summarized:

(1) No drift older than Wisconsin was found.

(2) Fresh erratics and roches moutonnées were found in abundance on enough critical uplands and summits to convince the authors that Wisconsin ice had completely glaciated the island.

(3) Newfoundland may have been glaciated by Labrador ice during an early phase of Wisconsin glaciation, as suggested by the warped surface of the wave-cut benches (Flint, 1939, p. 1909) and by striae at Port au Port.

(4) Newfoundland, in a late phase of Wisconsin glaciation, supported a local ice cap which moved outward to beyond the present shore line, rounding and scraping the bedrocks and hills and gouging the valleys to fiords. A subsidiary ice cap seems to have occupied the Avalon peninsula during some phase of deglaciation in order to produce the outward-trending striae of that area.

(5) Slight deglaciation resulted in recession of the land ice in many places within the present shore line with the accompanying deposition of a suite of drift, consisting of till, plain gravel, and kame gravel.

(6) Immediately following this episode, sea level was high enough to allow the deposition of extensive marine deposits over the lower glacial suite. The marine deposits are largely deltaic with fine silty bottom-set beds and sandy to gravelly fore-sets. These deposits are now found above present sea level rising progressively toward the north. Marine fossils, found in these sediments in many places, indicate normal

marine salinity and a water temperature much like that of the coastal waters of today.

(7) Slight readvance of the ice edge in the Bay St. George area and in some parts of the north coast caused deposition of till and kame gravel over the marine beds. The ice edge in the Bay St. George area at this readvanced position remained stationary long enough to build a fairly strong and continuous moraine from the Anguille Mountains to Port au Port.

(8) Small alpine glaciers excavated cirques at the heads of some of the shorter and steeper valleys on the higher flanks of the mountain masses and piled drift in small looped moraines below them.

(9) Post Wisconsin frost splitting has blanketed the uplands with felsenmeer, while weathering under a vegetal cover on flanks and lowlands has produced the podsol soil, characteristic of the region.

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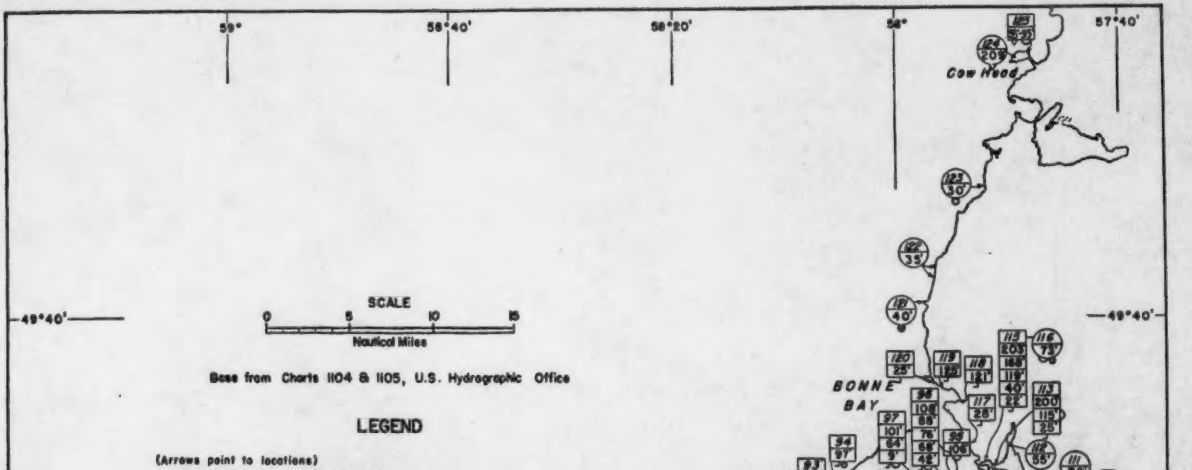
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(Arrows point to locations)

Base from Charts 1104 & 1105, U.S. Hydrographic Office

LEGEND

(Arrows point to locations)
(Upper number, in slant figures, is serial number of location.
Lower number, in vertical figures, is elevation in feet.)

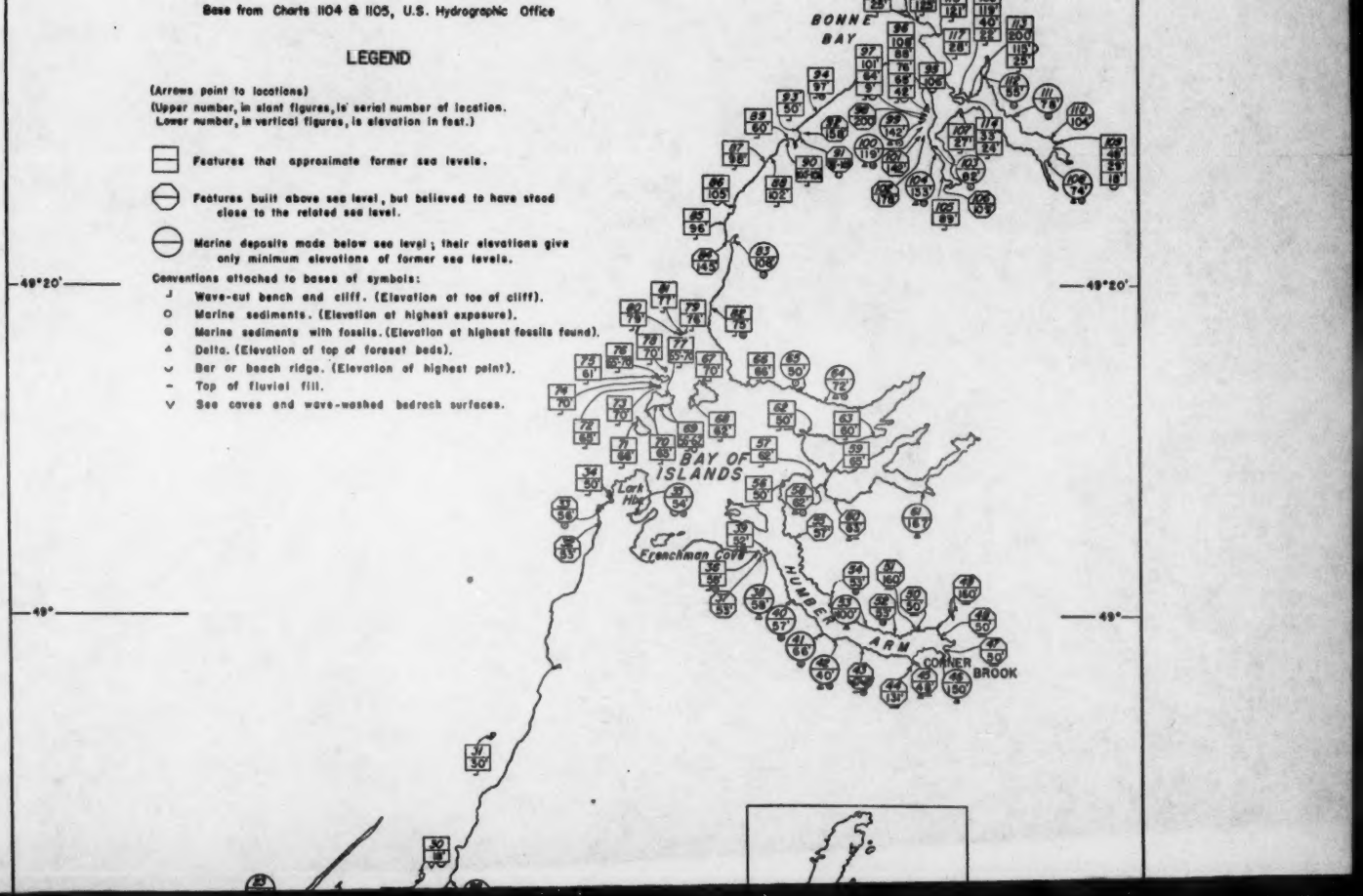
Features that approximate former sea levels.

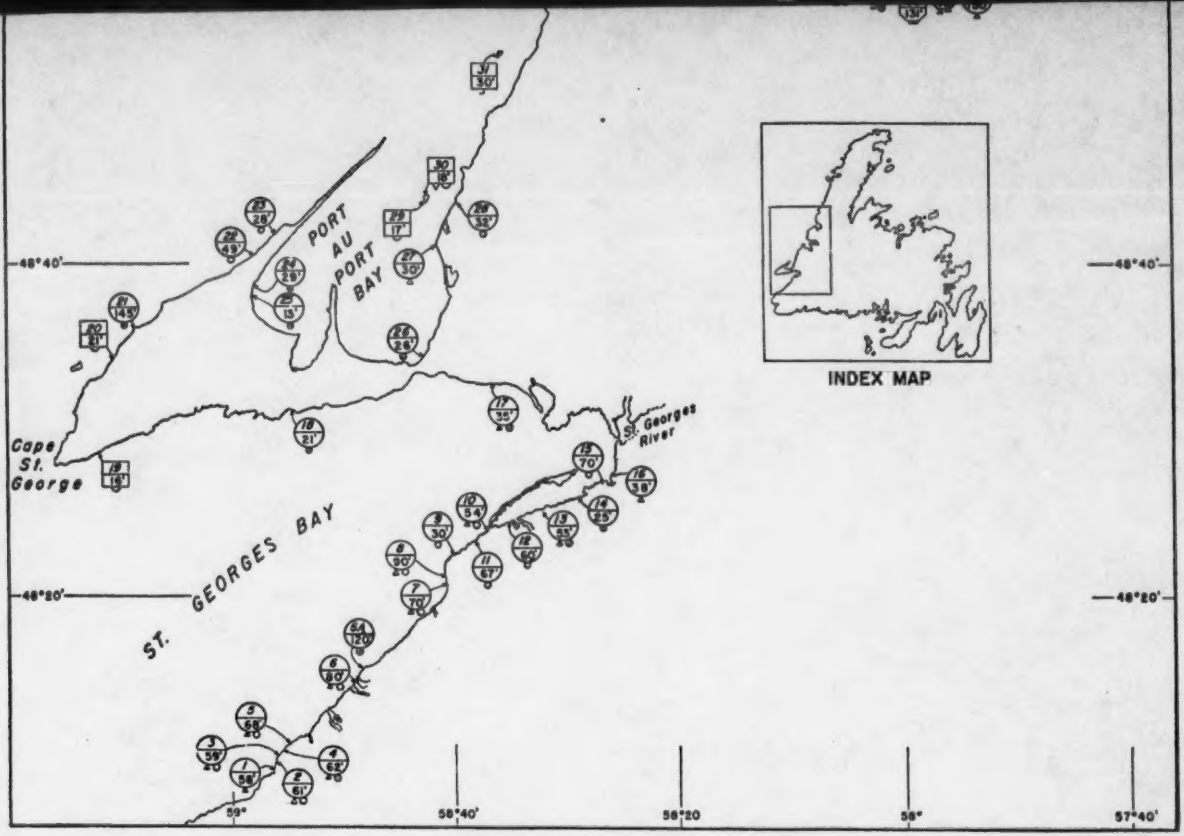
Features built above sea level, but believed to have stood close to the related sea level.

Marine deposits made below sea level; their elevations give only minimum elevations of former sea levels.

Conventions attached to bases of symbols:

- Wave-cut bench and cliff. (Elevation at toe of cliff).
- Marine sediments. (Elevation at highest exposure).
- Marine sediments with fossils. (Elevation at highest fossils found).
- Delta. (Elevation of top of foreset beds).
- Bar or beach ridge. (Elevation of highest point).
- Top of fluvial fill.
- Sea caves and wave-washed bedrock surfaces.





MAP SHOWING LOCATIONS AND ELEVATIONS OF FEATURES DISCUSSED

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LATE QUATERNARY CHANGES OF LEVEL IN WESTERN AND SOUTHERN NEWFOUNDLAND

BY RICHARD FOSTER FLINT

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ABSTRACT

Emerged Quaternary marine features are numerous along the west coast of Newfoundland, although their distribution is patchy. They include wave-cut benches and cliffs, localized constructional forms such as beach ridges, bars, and deltas, and a discontinuous blanket of fossil-bearing marine sediments. These features reach progressively higher elevations toward the north; their positions in long east-west bays indicate a westerly component in the northward rise.

The highest marine limit is very indistinctly recorded, but a lower strand line, cutting the latest glacial deposits, and rising northwestward, is well marked by wave-cut benches on weak rocks. Strand lines in intermediate positions are very weak, but wave-cut benches are well developed at present sea level. These facts indicate upwarping following deglaciation, the movement having been interrupted by one long pause and followed by another pause at present sea level.

No unequivocal evidence of emergence was found along the western half of the south coast, although emergence may be recorded farther east. The northwestward rise of the marine features along the west coast is consistent with (though it does not prove) the hypothesis that part or all of Newfoundland was invaded by the Labrador ice sheet during the latest (presumably Wisconsin) glacial age and that the warping was caused principally by unloading of the crust by the Labrador ice sheet during the same glacial age.

Evidence in two districts on the west coast indicates that at least part of the postglacial eustatic rise of sea level occurred while glacier ice was still actively present, and prior to at least part of the crustal warping.

STATEMENT OF THE PROBLEM

Study of sea-level and lake-level features warped out of horizontality by recovery of the crust from glacial loads has led to important glacial and geophysical conclusions and will certainly lead to still further conclusions as information increases. This paper contributes new data on the deformation of a small part of the southern sector of glaciated North America; the character and amount of deformation in the northern sector are still virtually unknown.

The place of Newfoundland in late Quaternary crustal warping has been a subject of speculation by DeGeer (1892, Pl. 13) and Fairchild (1918, p. 202) and was the object of two reconnaissance visits by Daly (1902; 1921; *see also* Daly, 1934, p. 105-106). Both DeGeer and Daly inferred upwarping of the Newfoundland crust toward the northwest; Fairchild inferred warping rising to a high point at the center of Newfoundland. As a result of reconnaissance observations incidental to stratigraphic studies, Schuchert and Dunbar (1934, p. 8-9) and Ingerson (1934, p. 178-203) put forward the view that emerged strand lines on the west coast of Newfoundland are essentially horizontal.

In view of these conflicting concepts, it seemed certain that a detailed examination of the west coast would clarify the data and afford an

improved basis for further study in adjacent areas. A favorable opportunity to make this examination was afforded during the summer of 1939, by reason of the similar study on the Labrador coast being made by Dr. V. Tanner, and of the geomorphic and glacial-stratigraphic investigation of Newfoundland planned by Drs. W. H. Twenhofel and Paul MacClintock. All these projects, including the one that forms the subject of the present paper, were carried out under grants from the Penrose Bequest of The Geological Society of America, as parts of a loosely co-ordinated whole.

ACKNOWLEDGMENTS

Thanks are due not only to the Geological Society but to Drs. Twenhofel and MacClintock for helpful and stimulating discussion during field conferences and for data from parts of Newfoundland not visited by the writer. Dr. MacClintock also added materially to the collection of fossils made during the season. Dr. Tanner helpfully discussed problems of mutual application to Newfoundland and Labrador in a conference after the close of the field season. Dr. A. K. Snelgrove, Director of the Geological Survey of Newfoundland, cordially facilitated the work in a number of important ways. Mr. Arnold C. Mason supplied certain detailed and helpful data from the Humber Arm, Bay of Islands. Mr. W. A. Bryan supplied the data at Location 6A (Pl. 1). Information from other parts of Newfoundland, kindly given by other persons including several officers of the Geological Survey, is acknowledged in the text. Drs. J. W. Goldthwait and J. B. Lucke offered helpful suggestions on the manuscript. Throughout the work efficient field assistance was rendered by Morris B. Canning and Sanborn Partridge, both of Yale University. The fossils collected were kindly studied by Dr. H. G. Richards of the New Jersey State Museum. His results are included in the present paper.

GEOLOGIC SETTING[1]

The structural grain of Newfoundland (Fig. 1) trends northeast-southwest and is developed in pre-Cambrian and Paleozoic rocks, both crystalline and sedimentary. These rocks, in most places conspicuously folded, were reduced by erosion to a rolling surface of low relief, which was then upheaved and rejuvenated, so that today it forms a broad plateau sloping gently southeast from a crest more than 2000 feet high along the west coast, to elevations of 600 to 700 feet along the east coast. The plateau is trenched by deep valleys which, on the west coast particularly, have been strikingly sculptured by glaciation.

[1] For discussions of the features mentioned here, *see* Schuchert and Dunbar (1934) and Twenhofel (1912).

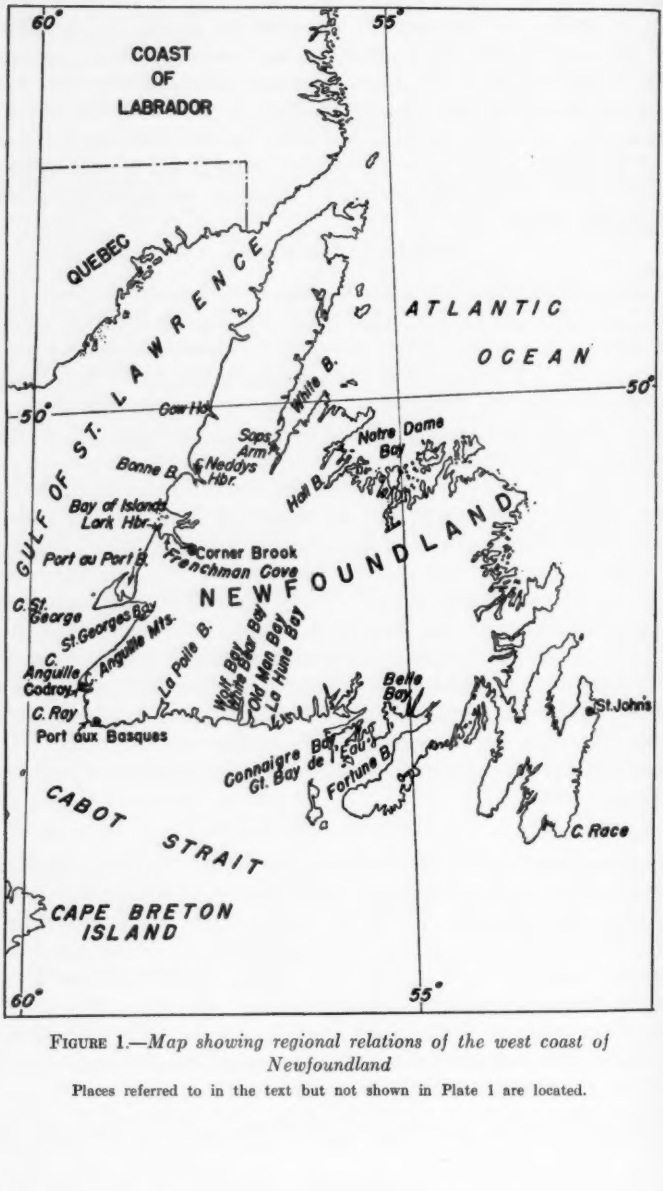

FIGURE 1.—*Map showing regional relations of the west coast of Newfoundland*

Places referred to in the text but not shown in Plate 1 are located.

The southern half of the west coast and the western half of the south coast, the sections traversed in the present study, differ conspicuously from each other. The south coast section consists chiefly of granites, gneisses, and schists. Its valleys, paralleling the grain of the rocks, have been submerged to form long deep fiordlike bays. Soil is scanty and even fishing settlements are few and small. On the other hand the west coast is developed on sedimentary rocks with local intrusives. Although the general trend of the coast parallels the strike of the rocks, the sea cliffs commonly transect the local structures. In some places the high plateau reaches the immediate shore, forming spectacular cliffs. In others the steep mountainous face of the plateau stands several miles east of the shore, behind a gently rolling piedmont lowland underlain by weak rocks. The soil is developed on glacial drift which in this region of softer rocks is far more abundant than along the western part of the south coast. In consequence the population is greater, and it is engaged not only in fishing but also in farming.

The cliffs are nearly everywhere bare and in most places they plunge down into deep water. Whatever the factors that originally determined this coast in preglacial time, it seems certain that the cliffs were considerably steepened and otherwise modified by glacial erosion and that they have been eroded also by postglacial weathering processes, notably frost wedging.

Newfoundland was strongly glaciated during the latest (presumably Wisconsin) glacial age. The conspicuous glacial-erosional features on most parts of the island indicate movement radially outward from a source or sources in Newfoundland. This evidence has raised the question, discussed more than once in the literature, whether Newfoundland was invaded by the great Labrador ice sheet or whether it supported its own ice cap. That both these possibilities may be true does not seem to have been entertained in the publications on the subject. The northwestward rise of the emerged marine features, observed by Daly and confirmed by the present study, strongly suggests that a great weight of ice, thickening northwestward, affected the crust beneath Newfoundland. Yet striae and related features record glacier flow outward from Newfoundland. However, features of this type ordinarily are a record of the latest movement; widespread erasure of evidence of earlier movements is demonstrated at many places in North America. This removes the conflict between the two hypotheses and replaces it with the probability that the Labrador ice sheet invaded part or all of Newfoundland in Wisconsin time and that, as this ice sheet shrank, local snowfall on the Newfoundland plateau maintained an independent glacier mass which flowed radially outward and persisted after Cabot Strait and

parts of the Gulf of St. Lawrence had been deglaciated. Similar relations now obtain in East Greenland, where the many isolated ice caps on the broad plateaulike areas of the coastal belt are believed to be the result of shrinkage of the Greenland ice sheet from its late Pleistocene maximum. If so, the directions of ice flow on the seaward margins of these ice caps are much the same as during the glacial maximum, but on the landward margins the direction of flow has been reversed.

Wherever emerged marine features are exposed in stratigraphic relation to the glacial drift, the marine features postdate the drift.

METHOD OF STUDY

GENERAL CONSIDERATIONS

Examination of strand-line features in Newfoundland is a very different kind of task from the tracing of similar features in the classic region of the Great Lakes. In the latter region generally open country, widespread cultivation, convenient roads, and easily eroded glacial drift as the basic material, permitting continuity of such features as wave-cut cliffs, reduce the difficulties to a minimum. In western Newfoundland the patchy distribution of the significant features, the dearth of roads and even trails, and a persistent growth of nearly impenetrable scrub fir and spruce make constant trouble for the investigator. The only effective transport is by sea, and harbors are few.

In view of these difficulties, it is certain that not all the significant features along the coasts traversed have been seen: in particular, the scrub may conceal many beach ridges the mapping of which would add considerably to the data collected. However, the west coast was traversed mile by mile from Cape Ray to Cow Head, including all bays and inlets. Where cliffs and scrub growth permitted, the shore was traversed on foot; elsewhere the shore was skirted by boat, usually at a distance of 100 to 200 yards offshore. Nearly all of the coast was examined twice; some stretches were seen repeatedly. The south coast from Cape Ray to Cape La Hune was followed by boat in the same manner, including all the bays except Old Man Bay and Little River, with trips ashore only at the places where gravel and sand exposures or benchlike forms were observed along this bare-rock coast.

For transport, the 40-foot auxiliary schooner ROSIE MARTIN, with crew of two, was first employed. After 2 weeks this vessel met with an unfortunate accident and sank in Port au Port Bay; during the rest of the season the 38-foot auxiliary schooner GRETA JUNE, with crew of three, was employed. The shallow draft (6 feet) of these vessels made it

possible to approach very close to shore; in exceptionally shoal places a fishing dory was used.

VERTICAL CONTROL

Detailed coast charts published by the U. S. Hydrographic Office served very well as base maps. These are scaled in nautical miles (about 6080 feet), and, because for some time to come coast charts are likely to be the best maps available for similar studies, all distances in this paper are quoted in nautical miles.

Vertical control is more important, and the reader must understand the method used so that he can judge the accuracy of the results, which are not precise. Elevations were determined with two Paulin altimeters, Type A-1, graduated in 2-foot intervals. The datum plane used was the high-water mark on the beach. Each point determined on an emerged marine feature was in a closed traverse, tied at both ends to the same point on the datum plane. The total traverse time away from the datum was in no case more than 30 minutes, and at most points it was considerably less. The two altimeters were checked against each other, and where discrepancies appeared the traverse was repeated. Checked between points of precisely determined elevation, this method has been found remarkably accurate. It was further checked in the field by hand level, with satisfactory results. Errors of observation or judgment in selecting (1) high-tide level and (2) the point to be measured (for example, a point on a wave-cut bench representing the related mean sea level) are likely to be greater than errors of actual measurement by the method used. Although the tide range on the west coast is not great, the error in determining the position of high tide may amount to 2 or 3 feet. Certainly the vertical difference between the toe of an emerged wave-cut cliff (especially one flanked by a small apron of rock waste) and the actual position of sea level at the time the cliff was made may amount to several feet. When the possible errors from these two sources are added, their sum is greater than the expectable error in measurement. Therefore, a more precise method of measurement seems unnecessary.

KINDS OF FEATURES OBSERVED

GENERAL STATEMENT

The marine features observed in western Newfoundland consist of (1) wave-cut cliffs and benches in bedrock, drift, and Quaternary marine deposits, (2) discontinuous blankets of marine sediments with and without fossils, and (3) localized constructional forms such as beach ridges, bars, and deltas. This list does not include the line marking the upper limit of wave washing of resistant rock headlands, a feature used

by Daly (1921, p. 382) for fixing the upper marine limit on the east coast, because on the west coast this line is inconspicuous or absent. This may be due in part to the lesser strength of the waves in the Gulf of St. Lawrence as compared with those of the Atlantic, but it is due chiefly to the weakness of the west-coast rocks, which are cliffed so rapidly that undercutting outstrips wave washing of the slopes immediately above. On the resistant rocks of the south coast, however, wave-washed headlands were observed, the upper limit of present-day washing reaching elevations of more than 50 feet on some headlands and less than half that figure on the less exposed surfaces within a few hundred feet of the point of the headland. This variation, especially conspicuous along the cliffs between Burgeo and Cape La Hune, implies that whereas wave washing may be used in reconnaissance work, its value in detailed local correlation is questionable.

WAVE-CUT CLIFFS AND BENCHES

Emerged wave-cut cliffs and benches in bedrock are confined mainly to the Bay of Islands surface, described later in the present paper. The only ones not clearly related to this surface are in Bonne Bay. All of them clearly transect structure, which in most places consists of steep dips in stratified rocks. It is significant that all the benches are cut into comparatively weak rocks, that most are confined to headlands, and that the areal distribution of modern wave-cut benches at present sea level is nearly identical with the distribution of their emerged predecessors (Pl. 2, fig. 1, inset). As far as it goes, this similarity suggests that no significant change in the direction of prevailing storm winds has taken place since the benches marking the Bay of Islands surface were cut.

On Tweed Island in the Bay of Islands an individual emerged bench is continuous alongshore through a distance approaching one (nautical) mile, and on Tweed and Pearl islands combined there is near continuity through 4 miles. Elsewhere the linear continuity of a single bench is rarely more than a few hundred feet; commonly it is considerably less. The seaward extent of the benches varies from 10 to 20 feet up to 200 or 300 feet, but as every emerged bench is bordered seaward by a modern bench its present width is no measure of its original maximum width. The angle of seaward slope varies from about 2 degrees to about 8 degrees; in general, the steeper slopes are on benches well exposed to storm waves. The detailed surface expression of the benches is determined by their lithology and structure. It consists commonly of low ribs controlled by resistant strata; in basic igneous rocks closed depressions made by differential abrasion or solution are present. On no bench

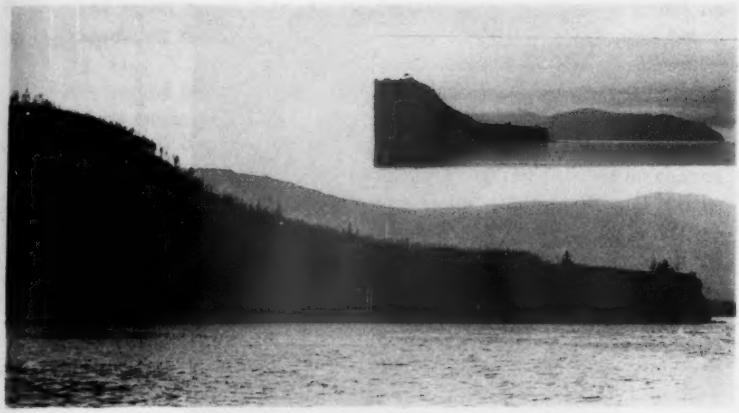

FIGURE 1. EMERGED WAVE-CUT BENCH ON STEEPLY INCLINED SHALE
Shoal Point, Bay of Islands (Pl. 1, Loc. 36). The bench is 250 feet long and is backed by a cliff. Inset is view at low tide showing part of the modern bench.

FIGURE 2. EMERGED WAVE-CUT BENCH ON COMPLEX ROCKS
View north at Trout River (Pl. 1, Loc. 91). The bench disappears toward the right and is replaced by a thick fill of clay, sand, and gravel graded to the same level as the bench.

EMERGED WAVE-CUT BENCH

On serpentinized basic igneous rock. Detail on north shore of Gregory Island, Bay of Islands (Pl. 1, Loc. 81). Note irregular surface of bench and partial grading of the cliff back of the bench.

is the local relief more than a few feet; the same relief is found on the corresponding modern bench immediately below the emerged bench (Pl. 4, fig. 1).

All the emerged benches lack continuous veneers of marine sediments, and many are quite bare. Commonly they carry scattered well-rounded pebbles and small boulders; this is equally true of the modern benches directly below and further suggests that there has been little or no change in the strength and direction of the storm waves since the principal bench-forming episode.

The cliffs back of the benches are variable in height and in angle of slope. In a few places cliff meets bench in a distinct angle; generally, however, the angle is subdued by accumulations of slide rock and slope-washed debris 5 to 10 feet thick, the thickness being closely determinable where the debris is exposed in section.

The cliffs back of a few of the emerged benches and many of the modern benches are notched, having at their bases an overhang with a vertical dimension from a few feet up to 30 feet or more. Nearly all the notches are controlled by lithology occurring where weak rocks lying at and just above sea level are overlain by more resistant strata (Pl. 5, fig. 2). Probably the relatively small number of notches observed back of emerged benches is explained by masking of the notches by slide rock and colluvium since emergence began.

Locally in Bonne Bay, wave-cut benches occur in till and in marine clay and silt. They are narrow and have steep seaward slopes; consequently they are faintly marked. These occurrences are restricted to protected shores where wave action is believed to have been relatively weak.

Several segments of the west coast consist of piedmont lowlands in siltstones, shales, and similar weak rocks. These gently rolling lowlands, extending seaward from the plateau front for a fraction of a mile up to several miles, show relief low enough to suggest wave-cut benches when seen from some distance offshore (Pl. 4, fig. 2; *cf.* Schuchert and Dunbar, 1934, Pl. 8B). In detail, however, the lowlands show the features normal to stream dissection with accompanying grading of slopes. They are not limited inland by cliffs, although in some places there is a sharp increase in slope where stronger rocks striking parallel with the coast are encountered. These changes in slope, suggesting, from a distance, gentle wave-cut cliffs, occur along the Cape Anguille Mountains and at places along the southeast coast of the Cape St. George peninsula.

The local presence of marine deposits on the hills of these lowlands is not proof of wave-cut origin, because much of the lowland area has been submerged since the last glaciation. Probably there is complete gradation from such lowlands submerged and later emerged without wave erosion

of bedrock, to true wave-cut benches. The flattened forms of some lowland hilltops, notably on the Cape St. George peninsula, suggest wave planation, and the presence on some of them of till reworked by waves, even where the bedrock relief is considerable and the topography is mature, proves that the sea has been present even though it may have affected the bedrock little or not at all.

LOCALIZED CONSTRUCTIONAL FORMS

Beach ridges.—In a few localities beach ridges were seen in abundance; their actual distribution, however, is probably far more extensive than their observed distribution. All those seen are built on open slopes free of timber. The impenetrable scrub that clothes much of the west coast undoubtedly conceals a great many ridges whose presence can only be suspected.

The ridges have been observed only on broad gentle slopes, of the order of 2 degrees or less. They consist chiefly of pebble gravel, the pebbles derived mainly from the local bedrocks but with a few foreigners presumably derived from the drift. Most of the ridges are no more than 2 or 3 feet high, and although commonly set close together vertically they show no regularity of spacing. In ground plan they tend to bunch or merge at small promontories and to separate where the general slope becomes gentler. As many as 15 have been observed in a single series.

The beach ridges are not believed to furnish evidence as to the rate or continuity of emergence of the localities where they occur; they indicate merely the fact of emergence.

Bars.—Minor features somewhat resembling bars occur at various points on the west coast; only three well-developed bars were noted. One is at Lark Harbor, Bay of Islands. There the two shoreward ends of a bay bar are truncated by the waves at present sea level and are connected below sea level by a bank concave toward the mouth of the bay. Exposures in the bar, the highest parts of which (at Lark Harbor settlement) stand at more than 50 feet above present sea level, show sand and pebbles, the latter chiefly similar to the local bedrock, parallel bedded and with grain size increasing vertically upward. Beds of fine sand either in or resting against the seaward base of the bar are rich in marine fossils. The elevation of this feature in relation to near-by wave-cut benches indicates that probably it was built under the control of the Bay of Islands surface.

The other two bars are at Neddy's Harbor in Bonne Bay. A high hill at the east entrance to the harbor is composed of vertical thin-bedded limestones. The headland forming the south slope of the hill is benched

FIGURE 1. MODERN WAVE-CUT BENCH
Green Point (Pl. 1, Loc. 121), showing truncated Ordovician limestones and shales exposed at low tide and backed by a steep cliff.

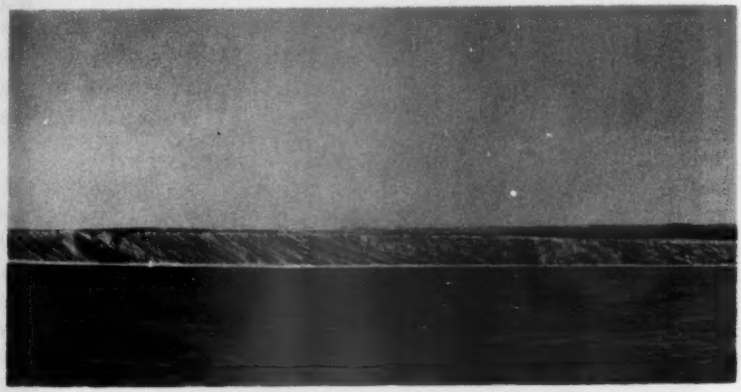

FIGURE 2. CLIFF AT CROW [GREEN] HEAD
On the Cape St. George peninsula (Pl. 1, Loc. 21), this headland exposing truncated shales is typical of broadly undulatory lowland areas, not backed by cliffs, which might be mistaken for wave-cut benches but are believed to be subaerially sculptured forms.

FEATURES ALONG THE WEST COAST

FIGURE 1. WAVE-ABRADED GRANITE BOULDER
On a pebble beach on the south shore of Tweed Island (Pl. 1, Loc. 70). The facet on the right faces the sea.

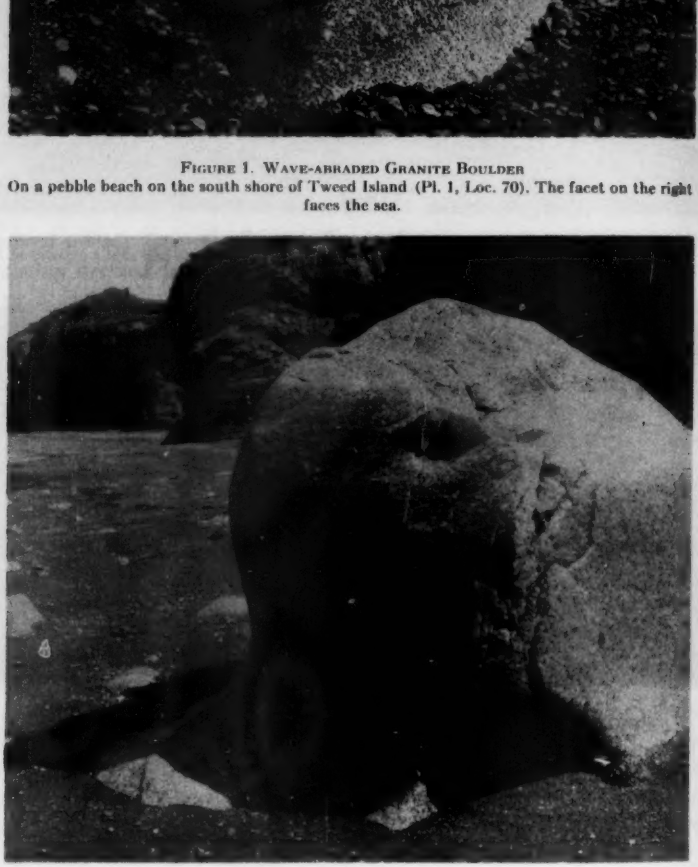

FIGURE 2. NOTCHED AND WAVE-ABRADED BOULDER
On a coarse-sand beach on the north shore of Tweed Island (Pl. 1, Loc. 77). Lithologically controlled notch in wave-cut cliff in background. (Photo by Sanborn Partridge).

WAVE-MODIFIED BOULDERS

at 200 feet and more broadly at 115 feet, clearly by wave cutting. The west flank of the hill carries a great accumulation of pebble gravel and sand, derived largely from the local limestone, the upper surface nearly flush with the bench at 115 feet and sloping gently northwest away from it. The constituent gravel and sand beds lie in long subparallel foresets inclined in the same direction, away from the bench. This accumulation represents the debris eroded from the headland, shifted alongshore, and dumped in deep water just west of the headland. Fossil-bearing fine-grained marine sediments are exposed at the outer base of this bar.

Sandy Head, on the west-facing peninsula that forms Neddys Harbor, consists of a core of till and fossil-bearing marine clay whose top has been truncated by the sea at an elevation of 73 feet, and the stones and coarser sand fractions thus concentrated from the till have been redeposited as a bar built southeastward from the headland. The crest of the bar slopes away from the headland, and its long section exposed in a modern wave-cut cliff shows long parallel foresets dipping with (but more steeply than) the crest.

The small number of bars, beach ridges, and similar accumulations on the west coast of Newfoundland probably reflects the small amount of loose material available for wave handling. Along the entire stretch of coast traversed, the till is thin and patchy, and, except in St. Georges Bay, stratified drift is concentrated largely in the valleys, at the mouths of which it occurs as deltas more commonly than in other forms.

Deltas.—The examination of the west coast was begun with a good deal of skepticism about the value of deltas for determining former sea levels, chiefly because many deltas are known to have been built in temporary bodies of fresh water dammed by glacier ice. However, so many of the deltas of the west coast are conformable with or grade laterally into fine sediments containing marine fossils, and the tops of so many fall into the plane of the conspicuous wave-cut benches, that most of them can be regarded with confidence as having been built in the sea.

The only information on water level that can be confidently inferred from an abandoned delta is that the water surface stood at least as high as the highest parts of the clearly defined foreset beds. How much higher it stood cannot usually be learned from the delta itself, as the depth of decapitation of the foresets by stream scour is unknown, quite aside from the possibility of gradual emergence and further planation of the foresets during this process. Therefore, although the deltas are useful confirmatory evidence of higher sea levels, the former water surfaces must be fixed by means other than the tops of the foreset beds.

In Bay of Islands the statistical evidence furnished by the approximate accordance of the tops of several deltas is believed to be of value. It is a commonplace that the upper surface of the topset beds in a delta rises upstream, and that the elevation at the outer edge of a cliffed delta varies with the amount of cliff recession that has occurred on it. However, most of the deltas in Bay of Islands end in deep water and hence have not been significantly eroded by cliffing; therefore the accordance of their tops at their outer edges is believed to lie near (though it certainly does not fix) the position of a former sea level to which they were built.

A truly remarkable composite delta forms the east shore of St. Georges Bay from St. Georges River southwest through 30 miles. Its foresets dip radially away from each of a dozen separate stream mouths. The elevation of its upper surface is not a reliable aid in judging the position of the sea level to which it was built, for its sea-cliffed front ends in shoal water, and therefore considerable retrogression may have occurred. On the other hand the elevation of the tops of the foresets varies through only about 20 feet, despite a greater variation in the thickness of the topsets. Therefore, whether this remarkably uniform surface separating foresets from topsets is a surface of stream scour or one of marine planation, it probably lies not far below the position of a former sea level.

LESS LOCALIZED MARINE SEDIMENTS

A general though discontinuous blanket of marine sediments is widespread along the parts of the west coast protected from the strongest wave action, notably in Bonne Bay and Bay of Islands. This material consists chiefly of silt and clay, for the most part delicately laminated and exhibiting various shades of gray and red according to the bedrock lithology in the vicinity. Mollusk shells occur in many parts of it, ordinarily in the coarser silts rather than in the finer-grained sediments. Although these sediments are continuous through a vertical range of more than 100 feet in some places, they appear to form a relatively thin mantle over glacial drift and bedrock. The name popularly applied to them along the whole coast is pug. The relation of these deposits to the deltas leaves little doubt that the two types of sediments are in part contemporaneous, although probably the fines were laid down during a longer time than were the deltas—*i.e.*, during the entire interval between the deglaciation of each locality and the present time. Undoubtedly emergence has been accompanied by erosion and redeposition of these fines, many times repeated.

On the outer coast, facing the Gulf of St. Lawrence, low-lying areas carry patches of much coarser deposits consisting of gravel and some

sand lithologically similar to the local till deposits but ordinarily with better rounding and smoothing of the pebbles and larger pieces. Material of this kind is always thin. It ranges from parallel-bedded to broadly cross-bedded. In some places it is exposed resting on till. It is believed to be a concentrate left by wave washing of till with removal of the fines and abrasion of the coarse residue.

Both these coarse concentrates and the pug are reliable confirmatory evidence of emergence, but neither gives more than a minimum figure for the position of sea level in any locality.

WAVE-ABRADED BOULDERS

The modern beaches and wave-cut benches are well supplied with granitic boulders, most of them residuals from glacial deposits. Some of these boulders are faceted and even undercut (Pl. 5, figs. 1, 2) on their seaward sides, which are smoothed and polished by abrasion in contrast with the rougher surfaces of their landward sides. On some boulders the seaward facet meets the adjacent lateral surfaces along a sharp edge or keel like that on a ventifact. These features are confined to boulders larger than about 2 feet in diameter and occur only where sand or small pebbles are abundant, burying the base of the boulder. Clearly the agent responsible is wave abrasion. The lack of these forms on small boulders is taken to mean that the latter are rolled or otherwise displaced by the force of the waves, so that they are worn more nearly evenly.

If boulders faceted, notched, or keeled in this manner are a criterion of wave abrasion, they may be taken, where found well above sea level, as evidence of emergence. Whether they record a relatively long stillstand of the strand line depends on the time required for sculpturing them, and unfortunately no data on the rate of their production were obtained. It is perhaps significant that the one locality where they were found above sea level is on a wave-cut bench in bedrock, thus furnishing independent evidence of a fairly long stillstand. The locality is Big Cove Head (Pl. 1, Loc. 88), where three large granite boulders were found projecting above turf-covered colluvium. The only difference between them and those at the modern strand line is that their faces have been roughened slightly by weathering.

CORRELATION OF DATA

DISTRIBUTION OF DATA

The map (Pl. 1) shows the areal and vertical distribution of the emerged marine features. The irregularity of their areal distribution depends on several factors. Along the south coast their absence is believed to indicate that no emergence has occurred. From Cape

Anguille northeast through 25 miles the coast is bordered continuously by high rock cliffs from which any significant features have been removed by recent wave erosion. The same is true of considerable stretches of the northwest coast of the Cape St. George peninsula and of the coast between Port au Port Bay and Bay of Islands. North of Cow Head the coastal lands are so low that the significant evidence, if present, lies several miles inland near the base of the Long Range escarpment. Even the higher points on the low coastal belt bear evidence of marine activity. Most of the districts in which emerged marine features are abundant are in slopes less steep than cliffs and are protected from the strongest waves.

BAY OF ISLANDS SURFACE

All but a very few of the wave-cut benches in bedrock integrate into a profile that rises northward along the coast. This profile has an elevation of 30 feet near the mouth of Port au Port Bay, 50 to 60 feet at the south entrance to Bay of Islands, 70 to 80 feet at its north entrance, 100 to 110 feet at Trout River, and 125 feet at the north end of Bonne Bay. Measured along the coast, the rate of rise is equivalent to about 1.7 feet per (nautical) mile. However, the benches occur up Bonne Bay through a distance of 7 miles southeastward, normal to the coast, and up Bay of Islands through 10 miles in the same direction. In both bays the benches diminish in elevation up the bays, so that their integrated profile rises northwest. The belt of observations is so narrow that the surface inferred from these profiles can scarcely be contoured with confidence, but the indications are that such contours would trend east-northeast, and that in a direction normal to the contours the rate of rise would approach 3 feet per (nautical) mile.[2] This trend is apparent from an examination of the wave-cut benches alone; if the deltas and similar features are used in addition, the inference is materially strengthened (Fig. 2).

The wave-cut benches that do not fall into this plane are so few, so poorly marked, and so far above or below the plane that they are believed not to invalidate the inference drawn—namely, that a single sea-level surface, warped so that it rises to the north-northwest, is recorded by the many conspicuous benches, and that at this level the sea was stable in relation to the land for a relatively long time—long enough to permit the benching of sedimentary rocks through widths of more than 200 feet. The benches and cliffs referred to this episode are so conspicuous in the mouth of Bay of Islands that their integrated surface is referred to here as the Bay of Islands surface.

[2] This is roughly equivalent to 2.5 feet per statute mile.

Extrapolation southward on this surface would bring it down to present sea level in the southern port of Port au Port Bay. However, the only feature found in the well-protected waters of that bay that is believed to approximate a former sea level is a single well-developed beach on Fox Island at 17-18 feet (Pl. 1, Loc. 30), and this falls so near the plane as to suggest that it may belong to the Bay of Islands surface.

HIGHER MARINE FEATURES

The Bay of Islands surface does not represent the upper marine limit on the west coast. The higher marine features, like those assigned to the Bay of Islands surface, occur at progressively higher elevations as they are traced north along the coast. However, the evidence consists mainly of deltas and other sedimentary accumulations, none of which is as reliable a sea-level indicator as are wave-cut benches. Plate 1 shows the distribution and elevations of the highest marine features at various points along the west coast. Only two of the features surely approximate the sea-level position: those at 200 feet (Pl. 1, Loc. 113) and 203 feet (Pl. 1, Loc. 115), respectively, at Bonne Bay. These are wave-cut benches and are believed to record the same sea level on two adjacent headlands. The feature (Pl. 1, Loc. 21) at 145 feet, on the Cape St. George peninsula, is a thin veneer of fossil-bearing marine silt on a bedrock surface. The feature at 209 feet at Cow Head (Pl. 1, Loc. 124) is the wave-washed summit of a hill higher than the adjacent country. All the others are deltas and similar fills, the elevations being taken on the eroded tops of the foreset beds. Hence, except for the two wave-cut benches, the elevations given are minima for the former sea levels. However, the points fall fairly well into an assumed surface striking northeast and rising northward; consequently these points possibly represent an approximate sea-level plane warped as suggested (Fig. 2). Search failed to discover any higher marine features along this part of the coast.

Southward projection of this assumed surface would carry it down to present sea level somewhere near Port aux Basques. No closer approximation of the intersection of the inclined profile of the highest marine features with present sea level was found possible, owing partly to the high cliffs already described, extending from Cape Anguille northeast through 25 miles, and partly to the fact that emerged marine features were not identified between Cape Anguille and Port aux Basques. In spite of favorable gentle slopes on rather weak material, no cliffs, beaches, or other records were found, although Hayes (Richards, 1937, p. 457) has noted fossil shells in clay at Codroy at an elevation of about 15 feet. On the contrary, outwash with fluvial stratification, till unmodified by wave washing, and kettles extend down to very low eleva-

tions. Further, the stratified fill in the valley of the Great Codroy River, unlike the fills on the west coast, appears to have been graded to present sea level or to some surface below it. These facts are surprising in view of the altitudes of marine features farther north. The

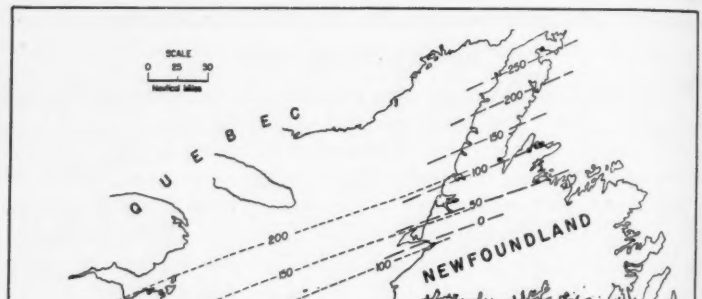

FIGURE 2.—*Map showing tentative isobases on three former sea-level surfaces suggested by field data*

The interpretation represented by the isobases is in no sense final or definitive. It is suggestive only and is subject to revision when further data are available, especially from eastern Newfoundland and from the Maritime Provinces.

absence of evidence from the coast between Cape Anguille and Port aux Basques may be explained in at least two ways: (1) The profile of the sea level to which the deltaic features in St. Georges Bay were built slopes southeastward more steeply than the foregoing statements have implied. (2) The coast between Cape Anguille and Port aux Basques was still largely covered by glacier ice while the features farther north were fashioned at sea level, and this ice acted as a buffer that prevented contact between the sea and the subglacial land surface. The latter interpretation seems the more probable, in view of the evidence (detailed in a later section) that the features built at this time in St. Georges Bay were built in immediate proximity to active glaciers. A

similar explanation, as indicated beyond, may account for the lack of any emerged marine features along the western half of the south coast of Newfoundland.

EVIDENCE ALONG THE SOUTH COAST

The south coast was examined in detail eastward to La Hune Bay, an airline distance of 100 (nautical) miles from Cape Ray. All the larger bays, including La Hune Bay, were examined. No wave-cut benches and cliffs were found, in spite of excellent exposure along this generally barren coast. This fact in itself does not justify the inference that the land has not formerly stood lower with respect to sea level, because the rocks are crystallines of very resistant types—chiefly granites and granitic metamorphics—which might withstand long-enduring wave attack without being benched. However, each of the major fiordlike bays has at its head a fill of outwash that descends to sea level. These fills are in striking contrast to the outwash fills on the west coast, which characteristically end in deltas high above sea level. Evidently the fills along this part of the south coast were graded either to the present sea level or to some level still lower. The fact that no remnants of higher fills were found strongly supports the inference that the land has not stood lower in relation to the sea since this part of the coast was freed from glacier ice. This inference receives further support, albeit less strong than could be wished, from the configuration of the sea floor at the heads of Wolf Bay, White Bear Bay, Old Man Bay, and La Hune Bay. The soundings shown on Chart 2416 (U. S. Hydrographic Office) suggest sizable deltas with the breaks of the crests of their distal slopes occurring at depths ranging between 30 and 120 feet below sea level. Whether or not these features have been subjected to further submergence since they were built (the depths of the breaks suggest that they have), it is very probable that similar deposits would occur at higher elevations, if the sea had formerly filled these bays to a higher level after they had been emptied of their glaciers.

The absence of emerged marine features from La Poile Bay has been noted by John R. Cooper (personal communication), and in his examination of Bay Despoir Jewell (1939) reported no such features.

Farther east along the south coast, however, the facts seem to be otherwise. D. E. White (personal communication) reports emerged deltas up to an elevation of about 50 feet, built in immediate proximity to glaciers, from Belle Bay, Fortune Bay; and K. Widmer (personal communication) reports wave-cut benches and related fills up to about the same elevation in the vicinity of Connaigre Bay and Great Bay de l'Eau (Fig. 2). Fossils have not yet been reported, but there seems little doubt that these

features are marine. If they are, two possibilities may be considered: (1) The zero isobase on the highest inferred marine surface on the west coast passes eastward through southwestern Newfoundland and then turns southeast, leaving Newfoundland and trending toward the Grand Banks. But this is not consistent with our present information on the emerged marine features of the east coast, nor has so sharp a swing in late Quaternary isobases been observed elsewhere in northeastern North America; the upwarping seems to have taken place on a very broad scale. Therefore this explanation is regarded as unlikely, unless it can be shown that the weight of local glaciers on Newfoundland induced strong irregularities in the warping. (2) The second possibility is that the features identified by White and Widmer are related to a sea level or sea levels slightly older than any represented on the west coast and warped up at a slightly earlier time. On this hypothesis the western half of the south coast and all of the west coast were still protected from marine attack, at this early time, by glacier ice flowing outward from Newfoundland, preventing registration of this strand line there. The relatively low eastern part of Newfoundland was almost certainly deglaciated before the high western region lost its glacial cover; furthermore, as already stated, glaciers were still active on the St. Georges Bay coast when the highest marine features observed there were being made. Hence the idea that shore features in southeastern Newfoundland were made relatively early in the deglaciation seems so probable that the matter deserves careful checking when the east coast strand lines come to be studied in detail.

It does not seem inherently improbable that warping affected the crust in southeastern Newfoundland. The zero isobase in southeastern New York, for example, is inferred to lie about 75 miles north of the southern limit of glaciation in that region. (*Cf.* Daly, 1934, Fig. 64.) In Newfoundland, the maximum possible limit of effective glaciation lies at the outer edge of the Grand Banks (beyond which any glacier ice would have been afloat). This limit is far more than 75 miles southeast of Cape Race. Even though we do not know the maximum extent of glaciation here, nor the thickness of the ice, nor the response of the crust to loading, the relationship cited fails to rule out the possibility of upwarping in southeastern Newfoundland.

INFERENCE FROM CRUSTAL WARPING AS TO POSITION OF GLACIAL CENTER

If the inferred crustal warping resulted from unloading of the crust by deglaciation, following an earlier loading by glaciation, the amplitude of uplift at any place should be related to the weight, and therefore the

thickness, of the glacier ice that formerly covered that place. If so, the pronounced northwestward rise of the marine features on the west coast implies that the former glacial mass was thickening toward the northwest. From this it may be regarded as likely that at least western Newfoundland was invaded by the Labrador ice sheet, flowing from the northwest, and that local Newfoundland glaciers were not massive enough to interfere seriously with the regional crustal influence of the Labrador ice. This inference is of relatively greater importance here than it would be in many other regions because of the extreme difficulty of applying ordinary drift-provenance study to the determination of the source of the principal glaciation of Newfoundland.

EMERGED MARINE FEATURES ON THE EAST COAST

Information concerning the east coast is very meager. Only a few figures besides those given by Daly (1921) have been published. A conspicuous bench on Hall Bay (Long. 56°05′), reported by W. H. Twenhofel (personal communication), as wave-cut on gravel, at 65 feet, and a well-marked beach at 105 feet on Sops Arm, White Bay (Long. 56°55′), reported by Heyl (1937, p. 3, amplified in an unpublished communication) fit closely into the Bay of Islands surface projected northeastward.

Three other features, reported by K. Watson (personal communication), also fit closely into this surface. They are: (1) a wave-cut bench in bedrock at 110 feet in Mings Bight (approx. Lat. 50°00′, Long. 56°00′); (2) a delta with top at 105 feet and associated with till, on Apsey Cove Brook, Baie Verte; and (3) a delta with top at 80 feet, containing marine fossils, and associated with till, on Main Brook, Baie Verte. The wave-cut bench is particularly suggestive of the Bay of Islands surface in that it implies notable crustal quiescence.

Another probable correlation with the Bay of Islands surface is the wave-cut bench at 250 feet at Howe Harbour, Hare Bay (Lat. 51°20′), reported by Cooper (1937, p. 3). This bench bevels serpentinized peridotite and must therefore represent a significant crustal stillstand. This in itself suggests the Bay of Islands surface; also this surface, projected northward without change of slope, would lie close to 250 feet at Howe Harbour. Although the connection is only suggestive, it is mentioned here for consideration in future study of northeastern Newfoundland.

The data on the east coast are too few to make profitable any further suggested correlations and must be supplemented by new information.

EVIDENCE OF DISCONTINUOUS EMERGENCE

Discontinuity in the upwarping of western Newfoundland is indicated by the conspicuous wave-cut benches in bedrock on two planes—the Bay

of Islands surface and present sea level. The broad development of the benches on these two planes, and their extreme rarity at other elevations, seems to allow of no other interpretation. If unloading of the crust by deglaciation is the prime cause of the upwarping, then it seems possible that the temporary stability at the Bay of Islands plane was brought about by cessation of deglaciation, or even pronounced re-expansion of the Labrador ice sheet, during the general waning of the glaciers. A pause of the order of 5000 years is believed sufficient to account for the observed benching at the Bay of Islands plane, but there seem to be no data on which to base even a guess as to how long ago this pause came to an end. If such dating could be established, it might be possible to correlate this event with some episode in the history of the Great Lakes region.

As the modern wave-cut bench seems to indicate stability comparable in duration with the stability at the Bay of Islands plane—that is, of the order of 5000 years—one is led to wonder whether the modern benching does not postdate the well-known climatic optimum, thus coinciding with a time of supposedly stable sea level.

This introduces the related question as to whether this region is being warped at present. At a number of points along the west coast, fishermen reported shoaling water measured in terms of a generation or two. Those reports which could be followed up (all of these referred to localities south of Port au Port) proved to relate not to bare-rock features but to sand or mud bottoms, thereby permitting explanation on a basis of shifting sediments without change of position of either the crust or the level of the sea.[3]

TIME RELATION BETWEEN CRUSTAL WARPING AND RISE OF SEA LEVEL

At several points along the southeast coast of St. Georges Bay, marine sediments occur interbedded with locally thick layers of till, the base of the highest till zone in this relationship lying at an elevation of 40 feet. The nature of the exposures and the relation of the till to conspicuous moraines rule out the possibility of slumping; the relations clearly indicate active glacier ice moving over a shallow sea floor. It is inferred that the sea level had risen (presumably because of return of meltwater to the sea) to the stratigraphic position of the zone of interbedding while active ice was still present in these places, and before at least the last 40 feet of crustal warping was recorded here. A similar relationship has been reported by Coleman (1926, p. 213).

[3] On the other hand, A. K. Snelgrove states that fishermen in Notre Dame Bay (on the east coast in roughly the same latitude as Bonne Bay) assert a present emergence of bedrock features amounting to 12 inches per 100 years. From numerous accounts, Dr. Snelgrove and various members of Princeton University expeditions consider this a reasonable figure.

Comparable features are exposed also at Frenchman Cove, Bay of Islands, but as the critical zone is not far above present sea level the inferred time relations between sea-level rise and crustal warping at this place are less striking.

SUMMARY OF RESULTS

The results of the study may be briefly summarized as follows:

(1) Emerged Quaternary marine features are well developed on the west coast of Newfoundland, but their distribution is patchy and irregular.

(2) These features date from the last deglaciation; they rise toward the northwest, and the rise is attributed to glacial unloading.

(3) The highest features in any one district are rarely strongly marked; they are referred to an early episode when glaciers were still present on the coast.

(4) A lower and later set of features, including prominent wave-cut benches, is distinct, as are the features now being made at sea level.

(5) Features at various intermediate positions occur but are weak compared with the two sets mentioned in (4). Hence it is inferred that crustal recovery was interrupted by two pauses, one of which is still in effect.

(6) Some of the postglacial rise of sea level occurred while active glaciers were still present on the coast, and this preceded at least part of the crustal warping.

(7) The inferred upwarping toward the northwest favors the hypothesis that Newfoundland was invaded by the Labrador ice sheet during the last glaciation.

RELATION TO EMERGED MARINE FEATURES IN OTHER REGIONS

MARITIME PROVINCES

Goldthwait (1924, p. 15) briefly described emerged Quaternary marine features in Nova Scotia and New Brunswick and published a map showing 100-foot isobases on these features, based on the assumption that all are referable to a single sea level. The elevations given are those of the highest marine feature at each place, but it is possible, as recognized by Goldthwait (personal communication), that not all the features measured are referable to the same sea-level plane. The grouping of the elevations in Nova Scotia does in fact suggest that this may be the case. On this interpretation, the disturbing sharp curves in the isobases can be eliminated. The six points recorded by Goldthwait from Nova Scotia and the Bay of Fundy shore of New Brunswick permit

the construction of isobases that continue, scarcely bending at all,[4] northeast across Cabot Strait and correlate with the features reported by White and Widmer in the Fortune Bay district in Newfoundland. The points on the east coast of New Brunswick, south of Gaspé, fall into a lower and less steeply inclined plane parallel with the plane inferred for Nova Scotia, and continuing northeast without bending, into the plane inferred in the present paper from the highest marine features in western Newfoundland (Fig. 2). Perhaps waning glacier ice covered a large part of New Brunswick while the sea was washing the already deglaciated Nova Scotia region; and that the sea was thus permitted to reach back toward the St. Lawrence only after further deglaciation and a certain amount of upwarping. This general relationship occurs in Fennoscandia and would seem to be the expectable result of gradual shrinkage of a large ice sheet.

Although the suggested correlations between Newfoundland and the Maritime Provinces are based on nothing more than apparent collinearity of the isobases in the two regions, they seem probable from the facts available at present.

If these correlations should prove to be valid, then the relative inclinations of the three inferred planes would yield important information on the amount of differential warping that took place between the times of crustal stability when the shore features were made. However, speculation on this matter at present would be premature.

LABRADOR

The study of emerged marine features in Labrador now being carried out by Tanner will presently make available detailed information on this hitherto little-known region. For the present, it can be stated that no discrepancy exists between the data gathered in Newfoundland during the present study and those so far gathered by Tanner [5] in adjacent parts of Labrador.

SIGNIFICANCE OF THE FOSSILS

Dr. H. G. Richards, having examined the fossil collections, has furnished data from which Table 1 has been compiled. He states that all the species represented are living in northern waters today; probably most of them could be found adjacent to the Newfoundland coast. The faunas are similar to those of the late Wisconsin or post Wisconsin seas of Hudson Bay, James Bay, and the Gulf of St. Lawrence. The collec-

[4] The only additional data on Nova Scotia published since Goldthwait's work seem to be those of Guernsey (1927, p. 72), who found some indication of postglacial uplift in the western part of Cape Breton Island.

[5] Comparison of field data in conference, October 1939.

tions suggest only slight depths and indicate moderately salt to brackish water; probably none of them records normal oceanic salinity. This interpretation is in good agreement with the stratigraphic conditions inferred from the deposits that yielded the collections.

TABLE 1.—*Localities of occurrence*

(Locality numbers refer to Plate 1)

Localities	4	6	10	17	21	24	25	26	35	36	39	52	64	65	69	82	89	99	100	103	104	105	108
Ecology*	C		C	B	B		A			C	C		B		B	C	B	A	B	A	A	A	B
Gastropoda																							
Natica groenlandica Müller							x		x											x	x		
Buccinum undatum Linné							x													x	x		
B. tenue Gray									x						x							x	
Cylichna alba Brown									x														
Lora pleurotomaria Couthouy									x									x	x				
Pelecypoda																							
Saxicava arctica Linné		x			x		x	x		x	x		x		x	x		x	x	x	x		
Macoma calcarea Gmelin	x			x	x		x			x					x			x	x	x	x		x
Mya truncata Linné			x		x		x			x	x		x		x			x	x		x		x
M. arenaria Linné							x											x			x		
Mytilus edulis Linné										x					x			x	x	x			
Macoma bathica Linné					x																		
Serripes groenlandica Beck							x		x								x		x	x	x		
Cardium ciliatum Fabricius																							x
Astarte striata Leach									x										x				x
A. borealis Schumacker						x			x														
Leda pernula Müller					x													x	x		x		
Yoldia glacialis Wood							x										x						
Pecten islandicus Müller									x				x						x	x			
Nacula expansa Reeve																				x			
Cyrtodaria siliqua Spengler									x														
Cryptodon gouldii Philippi		x																					
Crustacea																							
Balanus sp.									x	x			x		x			x	x	x	x		
Fragments (indet.)		x		x				x			x	x						x					

*Ecologic conditions tentatively inferred by Dr. Richards:

A = Water moderately salt; depth probably 1 to 25 fathoms.

B = Water less salt than A; probably near shore and close to fresh water.

C = Water brackish; probably shallow.

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MARINE PLEISTOCENE FOSSILS FROM NEWFOUNDLAND

BY HORACE G. RICHARDS

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ABSTRACT

Thirty-one species of fossils are reported from the Pleistocene of Newfoundland. Moderately saline to almost fresh water is indicated; no great depth of water is suggested. The fauna probably dates from Late Wisconsin or post-Wisconsin time when the land was depressed because of the load of the ice.

INTRODUCTION

Several collections of Pleistocene fossils from Newfoundland have recently been received by the writer for determination. Dr. R. F. Flint and Dr. Paul MacClintock sent the fossils obtained during their field work of 1939 which was supported by a grant from The Geological Society of America. Material was also received from Dr. Helgi Johnson and other geologists working under the direction of Dr. A. K. Snelgrove of the Newfoundland Government Survey. Furthermore, fossils collected by Dr. J. Wheeler in 1937 are also included.

In order to make the present report more complete, the records mentioned in a previous paper by the writer (Richards, 1937) are included in the discussion.

PLEISTOCENE LOCALITIES IN NEWFOUNDLAND

In Table 1 are listed the various localities where Pleistocene fossils have been found. Locality numbers preceded by an F refer to the station numbers of Dr. Flint. In other cases the collector's name is given in parenthesis at the end of the reference. A few additional localities have

been recorded in the literature without exact determination of the species. These are omitted in the present list, although a few were mentioned in the previous report (Richards, 1937, p. 458).

Inasmuch as the fossils submitted to the writer were primarily to be used for the interpretation of geological data, an attempt has been made to record the probable Pleistocene ecological conditions of the various localities. While the writer realizes that it is extremely unwise to draw conclusions from such small faunas, it is hoped that the suggested interpretations of the various localities will be of some assistance to the geologist in unraveling the Pleistocene history of Newfoundland.

In all cases a cold sea appears to be indicated; the variations are in depth and salinity. However, it is probable that none of the localities represent normal oceanic salinity or any appreciable depth.

TABLE 1.—*Pleistocene localities in Newfoundland*[1]

West coast—north to south

1. Castor River, 15 miles north of Hawk Bay. (Wheeler) **A.**
2. Narrows, River of Ponds Lake. (Johnson) **A.**
3. Southwest feeder, Portland Creek pond. (Johnson) **A.**
4. Northeast side river, near mouth, Portland Creek. (Johnson) **A.**
5. Parsons Pond, eastern shore. (Johnson) **B.**
6. (F-148) Near mouth, Winterhouse Brook, Bonne Bay. **A.**
7. (F-149) Mouth of Shoal Brook, south arm, Bonne Bay. **A.**
8. (F-150) South end, St. Joseph's (Hell) Cove, south arm, Bonne Bay. **A.**
9. (F-151) Crouch's Brook, Bonne Bay. **A.**
10. (F-154) East side of mouth of main river, east of Lomond, Bonne Bay. **B.**
11. (F-297) Woody Point, Bonne Bay, near Whitehouse Creek. **B.**
12. Near Paynes Cove, Bonne Bay; elevation, 102 feet. (Schuchert and Dunbar, 1934) **C.**
13. (F-146) Trout River. **B.**
14. (F-141) North Head (between Bay of Islands and Cape St. Gregory). **C.**
15. Blow Me Down Creek, Bay of Islands, ¼ mile from shore. (Cooper) **B.**
16. Lark Harbor; 35-foot terrace, shells from about 15 feet. (Kemmerer) **B.**
17. (F-93) Lark Harbor.
18. York Harbor; clay bank along eastern shore; elevation, 8 feet. (Cooper) **B.**
19. (F-98) Shoal Point. **C.**
20. (F-101) Corner Brook, near railroad station.
21. Corner Brook; terrace about 250 feet back from shore and approximately 40 feet high. (Kemmerer) **C.**
22. (F-103) Lower Frenchman Head, Bay of Islands. **C.**
23. (F-104) 1000 feet west of 22. **C.**

A. Moderately salt water; probably 1-25 fathoms.
B. Less saline; probably near shore and close to fresh water.
C. Brackish; considerable admixture with fresh water; probably shallow.

[1] *See* Map of Newfoundland by Forest Engineering Department, International Paper Company, New York (1933).

TABLE 1.—*Pleistocene localities in Newfoundland (Continued)*

24. (F-106) Petipas Cove, Humber Cove, Bay of Islands.
25. (F-125A) Mouth of Stone Brook, north arm, Bay of Islands. **B.**
26. (F-126) Mouth of Liverpool Brook, north arm, Bay of Islands.
27. (F-130) Southeast Point, Tweed Island, Bay of Islands. **B.**
28. (F-65) Crow Head, St. George Peninsula. **B.**
29. (F-72) West Bay Landing, Port au Port Bay.
30. (F-74) Cove 600 feet south of 29. **A.**
31. (F-182) Southwest end, Youngs Cove, St. George Bay. **C.**
32. (F-191) 0.5 mile southwest mouth, Barrachois Brook, St. George Bay.
33. (F-199) 0.4 mile south Harbor Point, north of Highland Church, St. George Bay. **C.**
34. (F-204) 1 mile west Stevenville Church; elevation, 35 feet. (MacClintock) **B.**
35. Robinson Head; broken shells in outwash glacial sand 100 feet above tide. (Hayes)
36. Contact between delta and moraine between Middle Barachars Brook and Crabbes Brook, about 1 mile north of Jeffries. (MacClintock) **C.**
37. Codroy (Road); fragments 15 feet above tide. (Johnson)

North coast

38. Bay Verte. (Watson) **C.**
39. Brook, 1 mile west of Clam Pond, southern arm, Little Bay area, Notre Dame Bay. (MacLean) **C.**
40. Tilt Cove, Notre Dame Bay; elevation, 60 feet. (Murray, 1882) **C.**
41. Red marine silts at Springdale, White Bay. (MacClintock) **C.**
42. Botwood; 25 foot terrace on west side of Northern Arm Point. (Snelgrove) **B.**

A. Moderately salt water; probably 1-25 fathoms.
B. Less saline; probably near shore and close to fresh water.
C. Brackish; considerable admixture with fresh water; probably shallow.

PLEISTOCENE FOSSILS FROM NEWFOUNDLAND

PELECYPODA

Nucula expansa Reeve

3, 8, 15.[2]
Pleistocene: James Bay; Rivière du Loup; New Brunswick; Maine.
Recent: Labrador and North Shore Gulf of St. Lawrence; 30 fathoms.

Leda pernula Müller

2, 3, 6, 7, 11, 28.
Pleistocene: James Bay; Rivière du Loup; New Brunswick; Maine.
Recent: Greenland to Massachusetts Bay; Hudson Strait.

Yoldia glacialis Wood

13, 30.
Pleistocene: James Bay; Rivière du Loup; Montreal; Ottawa; Lake Champlain, Vermont; New Brunswick; Maine.
Recent: Hudson Bay and Strait.

[2] Numbers refer to localities given in Table 1.

Pecten islandicus Müller

3, 5, 6, 8, 17, 18, 25.
Pleistocene: Hudson and James Bays; Labrador; Rivière du Loup; New Brunswick; Maine; Long Island, N. Y. (Gardiner's Clay)
Recent: Greenland to Cape Cod.

Mytilus edulis Linné

5, 6, 8, 16, 18, 19, 27, 42.
Pleistocene: Hudson and James Bays; Greenland; St. Lawrence Valley; Champlain Valley; New Brunswick; Maine; Massachusetts to South Carolina. (Interglacial)
Recent: Greenland to North Carolina; Hudson and James bays.

Modiolus modiolus Linné

3.
Pleistocene: Montreal; Sankaty Head, Mass. and South Carolina. (Interglacial)
Recent: Arctic Ocean to North Carolina.

Astarte borealis Schumacker

4, 17, 29.
Pleistocene: Hudson and James Bays; Greenland; Labrador; Maine.
Recent: Of northern distribution, the exact range being uncertain because it has been confused with *A. arctica* Gray.

Astarte striata Leach

2, 3, 5, 6, 10, 15, 17, 18, 42.
Pleistocene: Hudson and James Bays; Greenland; Maine.
Recent: Davis Strait to Massachusetts Bay. It is difficult to ascertain the exact range because this species has been confused with *A. banksii* Leach and *A. compressa* Linné.

Thyasira gouldii Philippi
(*Cryptodon gouldii* Philippi)

17.
Pleistocene: Montreal; Vermont.
Recent: Greenland to Connecticut.

Cardium ciliatum Fabricius

5, 10, 15.
Pleistocene: James Bay; Greenland.
Recent: Greenland to Cape Cod.

Serripes groenlandica Bruguière

1, 3, 6, 7, 8, 13, 17, 30.
Pleistocene: Greenland; James Bay; Labrador; Rivière du Loup; Quebec; New Brunswick; Maine.
Recent: Greenland to Cape Cod.

Macoma calcarea Gmelin

2, 3, 5, 6, 7, 8, 10, 15, 16, 17, 18, 27, 28, 30, 33, 34, 36, 39.
Pleistocene: Greenland; James Bay; Rivière du Loup; Montreal; Champlain Valley; New Brunswick; Maine; New York City; New Jersey to South Carolina. (Interglacial)
Recent: Greenland to New Jersey.

Macoma balthica Linné

28, 34, 42.
Pleistocene: James Bay; St. Lawrence and Champlain Valleys; Massachusetts to South Carolina. (Interglacial)
Recent: Arctic Ocean to Georgia.

Mya arenaria Linné

1, 5, 7, 11, 30, 42.
Pleistocene: Greenland; James Bay; St. Lawrence Valley; Champlain Valley; Massachusetts to New Jersey. (Interglacial)
Recent: Greenland to Florida (rare south of New Jersey).

Mya truncata Linné

2, 3, 4, 6, 7, 8, 10, 15, 16, 17, 18, 21, 27, 28, 30, 33, 34, 36, 39, 40.
Pleistocene: Greenland; Hudson and James Bays; St. Lawrence Valley; Sankaty Head, Mass. (Interglacial)
Recent: Greenland to Massachusetts.

Saxicava arctica Linné

3, 5, 6, 7, 8, 11, 14, 15, 16, 18, 19, 22, 23, 25, 27, 28, 30, 33, 34, 41, 42.
Pleistocene: Greenland; Hudson and James Bays; St. Lawrence and Champlain Valleys; New Brunswick; Maine. Probably the most abundant of all northern (post-Wisconsin) Pleistocene species; New Jersey and North Carolina (Interglacial).
Recent: Greenland to the West Indies. However the heavy, coarse variety typical of the Pleistocene is limited to Arctic and sub-Arctic seas

Cyrtodaria siliqua Spengler

17.
Pleistocene: Labrador; Rivière du Loup.
Recent: Arctic Ocean to Georges Bank; 5 to 50 fathoms.

Venericardia borealis Conrad

2, 3, 4.
Pleistocene: Labrador; Massachusetts; Long Island and New Jersey. (Interglacial)
Recent: Labrador to off Cape Hatteras; deep water south of New Jersey.

GASTROPODA

Acmaea testudinalis Müller

3.
Pleistocene: Hudson and James Bays; Labrador.
Recent: Labrador to Connecticut; Hudson and James Bays; Gulf of St. Lawrence.

Natica groenlandica Möller

3, 5, 7, 8, 15, 16, 17, 18, 30, 34.
Pleistocene: Greenland; James Bay; Rivière du Loup; Montreal; Maine.
Recent: Greenland to North Carolina; deep water south of Cape Cod.

Littorina saxitile Olivi

(*L. rudis* Maton)

18, 42.
Pleistocene: Rivière du Loup.
Recent: Labrador to Cape May.

Margarites cinerea Couthouy

2.
Pleistocene: Rivière du Loup; Portland, Maine.
Recent: Greenland to Massachusetts Bay; 5 to 200 fathoms.

Buccinum undatum Linné

3, 7, 8, 30.
Pleistocene: Labrador; Rivière du Loup; New Brunswick; Maine; Sankaty Head, Mass.; New Jersey.
Recent: Labrador to deep water off Maryland.

Buccinum tenue Gray

1, 9, 17, 27.
Pleistocene: Greenland; Labrador; James Bay; Rivière du Loup.
Recent: Labrador to Gulf of Maine; more common in Pleistocene than in present seas.

Neptunea despecta Linné

3.
Pleistocene: James Bay; St. Lawrence Valley; New Brunswick.
Recent: Gulf of St. Lawrence to Massachusetts Bay and Georges Bank. Some of the specimens from Portland Creek Pond (Locality 3) resemble the coarser variety *carinata*.

Lora pleurotomaria Couthouy

(*Bela pyramidalis* of authors)

3, 6, 11, 17.
Pleistocene: Montreal.
Recent: Labrador to Massachusetts; 5 to 255 fathoms.

Lora scalaris Möller

(Bela turricula of authors)

34.
Pleistocene: Rivière du Loup; Montreal; Labrador.
Recent: Greenland to Massachusetts Bay; 10 to 190 fathoms.

Cylichna alba Brown

17.
Pleistocene: James Bay; Rivière du Loup; Montreal; St. Albans, Vt.
Recent: Greenland to North Carolina; deep water south of Block Island, R. I.

BRACHIOPODA

Rhynchonella psittacea Gmelin

3.
Pleistocene: Hudson and James Bays; Rivière du Loup; Montreal.
Recent: Polar Seas and Hudson Bay to Gulf of St. Lawrence.

CRUSTACEA

Balanus crenatus Bruguière

3, 6, 7, 8, 11, 17, 19, 25, 27, 34, 41.
Pleistocene: Labrador, St. Lawrence Valley; New Brunswick; Maine.
Recent: Labrador to Cape May.
The barnacle fragments from Newfoundland are tentatively referred to this species, although it is possible that other species are represented also.

DISCUSSION

Of the 31 species herein recorded from the Pleistocene of Newfoundland, all are known to be living today in northern seas, and probably most of them could be found in the waters adjacent to the Newfoundland coast.

Varying ecological conditions are indicated at the different localities. An attempt has been made to interpret the various localities in terms of salinity and depth. While such conclusions are very tentative, it was observed that a range between moderately saline to almost fresh water was indicated. Furthermore, a variation between shallow and moderately deep water was suggested. As would be expected there was a correlation between the more saline conditions and the moderately deep water. Those species most indicative of deep water are *Nucula expansa* Reeve, *Lora scalaris* Möller, *L. pleurotomaria* Couthouy, and *Rhynchonella psittacea* Gmelin. However, the fact that they usually occur with species characteristic of more shallow water suggests that no great depth of water is indicated. No further attempt will be made to interpret the various localities since that lies outside the scope of this paper.

The fauna is of Late Wisconsin or post-Wisconsin age; an attempt at a more exact dating has been made by the various geologists who were working in Newfoundland during the past summer (Flint, 1940; MacClintock and Twenhofel, 1940).

The fauna is very similar to that reported from other Late or post-Wisconsin localities in northeastern North America. It probably bears the greatest resemblance to the fauna reported from James Bay (Richards, 1936). Many of the Newfoundland species also occur in the Pleistocene of Rivière du Loup and Montreal; however, these two latter localities contain a larger fauna and probably indicate a deeper submergence (Dawson, 1871).

It is probable that these various northern Pleistocene faunas are approximately contemporaneous and that they were deposited shortly after the retreat of the Wisconsin glaciers from the region, while the land was still depressed because of the weight of the ice. The release of this load gradually caused the land to rise; consequently the sea withdrew, leaving these fossils on raised beaches or terraces.

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